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Popular Astronomy.

Vol. VI. No. 2. APRIL, 1898. Whole No. 52.

COMPARISON OF THE ATMOSPHERIC CONDITIONS IN THE CENTRAL AND EASTERN PORTIONS OF THE UNITED STATES WITH THOSE IN THE HIGH PLATEAUS OF THE SOUTHWEST.

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FOR POPULAR ASTRONOMY.

On November 18, 1897, I started East with a view of arranging for the publication of the catalogue of new stars discovered at the Lowell Observatory in Mexico and at Flagstaff, and on this journey and return, as well as during my visits to different Observatories in the East, and in the Mississippi Valley, made a particular point of watching the atmospheric conditions both day and night. The results of such a study are of interest to astronomers and general readers, for very few persons have ever made similar comparisons, and for that reason I shall give some account of the phenomena noted.

In the first place I desire to remark that having been at Flagstaff from May 5th to November 15th, I had during this period grown very familiar with the atmospheric conditions here and correspondingly unfamiliar with those elsewhere, and I fear was inclined to underrate the superb climate in which we live, splendid as I knew it to be both from our discoveries and from my recollection of the appearances formerly observed in the central and eastern portion of the United States as well as in Europe and in Lower Egypt.

Before starting on this long journey across the continent, which in its circuit represents a space of over five thousand miles, I would not have been audacious enough to ascribe to our own climate the full extent of the qualities which it possesses, in comparison with the meagreness with which these qualities have been bestowed elsewhere; in making a just and truthful comparison of this kind one has to encounter the wavering doubts of the uninformed, as well as the partisanship of persons committed to other places and unaware of the shortcomings of their own locations. In spite of the danger of being accused of partizanship for Arizona, I shall not hesitate to give as just a comparison as I can make, in the certain knowledge that should the statements be questioned now they will be confirmed and accepted hereafter.

From our experience here since 1894, it may be stated that we have on the average about 330 clear days in the year, and that what few days are cloudy are generally relieved by clear or partially clear nights. Thus when a snow-storm comes on in winter or a rain-storm in summer, it lasts only a day or two, and then gives way to the most superb sunshine, and a sky which for depth and beauty is unrivalled on the face of the Earth, and is commonly spoken of by us in daily conversation as "Arizona blue."

I have spent most of my life in the central part of the United States, in Missouri and Illinois, and have travelled widely over the country, with the exception of the Pacific coast: and nowhere on the continent have I seen a climate in any way comparable to that of the southwestern plateaus.

While residing at Berlin from 1889 to 1893 I saw much of the dreary, rainy and cloudy climate of northern Europe. During this period I journeyed through France, Switzerland and Austria, and travelled more leisurely through Italy, Greece and Egypt, and was enabled by these excursions (two months in Italy, three weeks in lower Egypt and six weeks in Greece) to form a fair estimate of the climates accessible to Europeans. None of the countries which I have visited have climates in any way comparable to those of Arizona, or New Mexico, with possibly the exception of Egypt which is very much like the region of Phœnix in the Salt River Valley of southern Arizona. This latter is thoroughly tropical, only about 1200 feet above the sea, and is more like lower Egypt than any other part of this continent with which I am acquainted. In Germany and the rest of northern Europe (including England) there is a great amount of moisture, and certainly over half the days of the year are cloudy, rainy or foggy; and even on the days which are there counted as "clear," the clouds are numerous. In the months of May, June, July and August of 1891, I was using the large refractor of the Royal Observatory of Berlin, and even during these summer months there was hardly a night when several hours were not cut off by the clouds. Sometimes it would be cloudy at sunset, but more generally about midnight, when the clouds would come on with astronomical regularity and go away in about two or three hours. The climate is excessively moist and during the winter season the Sun is sometimes invisible for whole weeks, or even fortnights. This dreary and cloudy climate is characteristic of northern Europe, while Italy is favored by a climate similar to that of the United States, and on that account we hear much of the

"famed Italian skies." As a matter of fact, I estimate that the skies in Italy are less clear and less blue than in most parts of the United States, but their fame among Europeans is derived from the contrast with the dreary climate of northern Germany.

In Greece the climate is probably clearer than in Italy and the mountain scenery is incomparably more impressive. The sky has a fine blue, and the mountains at a distance of say ten miles have a hue closely approaching indigo; this color is sometimes mixed with red, and thus becomes purple of the most gorgeous character. This remarkable color of distant Grecian mountains is due to a selective absorbtion in the atmosphere, and the chromatic effect which results from it was fully appreciated by the beauty-loving Greeks of antiquity.

As regards Egypt, that country is a desert except where irrigated by the Nile, and so sharp is the boundary between the fertile valley and the sandy waste, that a man can step from one to the other at one stride.

The climate is excessively dry, the rainfall at Cairo being only about one and one-half inches per year (as we were assured by the Director of the Khedivial Observatory); the only clouds visible in March (1891) were high cirrus such as are seen occasionally in Arizona and more frequently at Mexico. The sky is blue, but seems to have a reddish tinge near the horizon (due to dust); and I imagine that in the hottest season the whole heavens must become more or less yellow or milky from the same cause. The climate is thoroughly tropical, and it is said that there are no violent winds. As almost the whole year is clear, I should think that for observations high above the horizon the conditions would be as good as could be had in any country almost on the level of the sea.

Of all the countries I visited, while in Europe, Egypt seems by far the best suited for astronomical work; yet Algeria is a similar country, and Mr. Lowell's tests there did not indicate great steadiness of atmosphere. Hence we may fairly doubt whether extremely good conditions can be found in the dry region south of the Mediterranean, which is marked by clear hot weather and situated at a low or at a moderate elevation above the sea. This much with regard to the climates accessible to Europeans.

Here in America our climate in most places is moderately clear —the sunny days probably varying from about 100 to 330 in a year—but the amount of moisture is very different in different places, and where moisture is combined with smoke and dust and conflicting currents in a dense atmosphere almost all grades of hazy and unsteady seeing can be produced.

As Mr. Boothroyd and I passed through Arizona and New Mexico on the recent journey we began to note the absence of "Arizona blue" in the sky; and when we had reached Kansas the sky had assumed the appearance of a moderate blue fringed near the horizon with yellow or whitish edges, such as we generally observe in the Mississippi Valley or in the eastern states. When we crossed the Mississippi river into Illinois, and night came on and the stars shone out, we noticed how dense and hazy the horzons became; and when we approached Chicago we could hardly believe the sky we were beholding was the familiar appearance of a few years ago, which we then considered very good.

We both repeatedly remarked that in such an atmosphere it was quite impossible to work with much effect within thirty degrees of the horizon; indeed the atmosphere seemed so hazy that the whole aspect of the heavens, as familiar to us in Arizona, was entirely changed. Many of the naked eye southern stars were lost in the haze, and the outlines of familiar constellations could be traced with difficulty.

On reaching Boston I found conditions in the East essentially the same as in Chicago; at Washington they were decidedly worse, and indeed the worst I have seen on the American continent. Not only is the sky cloudy, and rain very frequent, and the moisture correspondingly great, but there is thus engendered a haze or fog which is characteristic of the lowland near the Atlantic.

In examining stars with Professor Brown, who has labored faithfully with the great equatorial, only to be discouraged with his results, I found the images violently agitated, and the definition so bad that I could not separate a star separated by 0″.6 or 0″.7, while in the case of τ Cygni the duplicity was recognized with the utmost difficulty even when I knew the theoretical direction of elongation. The bodily motion of the image was most noticeable, since we see almost nothing of that in Arizona; and it recalled to me the dancing I used to see in the 9-inch refractor at Berlin. When we examined Neptune we could with difficulty distinguish it from a fixed star, so broken and unsteady did the limb appear. Not only do the clouds, haze and moist currents greatly interfere, but apparently also the cold walls of the dome itself. For the dome is of stone and iron, on which the moisture condenses in drops, and the air within is better adapted to give the observer rheumatism than good seeing. Such a dome, according to the effects observed by Mr. Douglass and the writer, must have a very injnrious effect upon the definition. Indeed we

are convinced that the ideal dome is that of the heavens itself—no covering at all; but if a dome must be had to protect the telescope from the weather, it should not be iron and stone but something like wood or canvas which will have as little effect on the surrounding air as possible.

At Philadelphia and at Charlottesville, Virginia, the atmosphere seemed to be similar to that at Washington, but was apparently a little less moist, and on the whole somewhat better.

At the University of Missouri Professor Updegraff was kind enough to give me the use of the 7½-inch refractor which I used when an undergraduate, and I found the seeing decidedly better than on the Atlantic coast, but in no degree comparable to what it is on the plateaus of the southwest.

On our return from Kansas City the rain continued till near the western boundary of Kansas, and as we approached La Junta we found the ground covered with snow and the sky clear and moderately blue. As we passed the highest point in Colorado (state line, which is over 7600 feet above the sea) we found the sky deep blue, but not so deep a blue as we ordinarily find in northern Arizona. On reaching Flagstaff the pines and the sky at once recalled our accustomed site. The contrasts with what I had seen in the East was so great that it could not fail to stir my enthusiasm. There arose the fine forest of green pines, and above them the mountains 13,000 feet high and wrapped in snow; still higher shone "Arizona blue" extending from the horizon to the zenith, and unbroken by a single cloud. So dark blue is this sky that we notice no appreciable whitening as we approach the Sun, or the horizon, which is free from dust and seldom interrupted by a cloud (and of course never by haze or fog.) I have never seen, in any part of the world, a more impressive scene than the Arizona sky when viewed through the beautiful pine forest which surrounds the Observatory. The Moon stands out sharply in the most beautiful silver light, and we can see with the naked eye as much detail of her mountains as one commonly sees elsewhere with an ordinary opera glass. Nothing could be more striking than this naked eye appearance of the Moon, and we have all repeatedly remarked how much it resembles a photograph taken with a small telescope.

The climate in Mexico gave us a very transparent air (most of the time,) but a sky much more broken by clouds; cirrus and the form known as "mackerel sky" were the most common appearances. The seeing there was on the whole inferior to what it is in Arizona, because of the winds which blow over the surrounding

mountains, and produce disturbing currents by the mixture of hot and cold air.

In the above discussion of climates, I have taken no notice of the character of the currents which effect seeing, for these can only be observed with a telescope, and as yet are very imperfectly known. I believe, however, that the estimates I have implied in the above statements are on the whole trustworthy. For good seeing at night, and during the day, we need a high and dry table-land, a clear climate and a location in a forest (to avoid too violent heating during the day.) In addition we must have a quiescent condition of the atmosphere, a region of calm, in which the currents are reduced to a minimum, if we are to obtain the best definition.

Professors Moore, Abbe and Bigelow, of the Weather Bureau, assured me while in Washington that the general region in which we are located secures this condition of meteorological equilibrium, freedom from disturbing currents, more fully than any other with which they are acquainted. The winds along the Pacific coast go up towards Oregon and Washington; those from the North come down East of the Rocky Mountains and pass into Colorado, Kansas and northern Texas, and are seldom felt in Arizona (we almost never have a north-east wind here;) the winds from the south-west divide, the southern streams passing south of us over the northern part of Mexico, the northern currents traversing California; what remains of the original flow passes over northern Arizona (our prevailing wind is from the southwest.) We are thus in a region more nearly calm than any other place yet found in the United States and I attribute to these meteorological circumstances the fine climate, and remarkable seeing which it has been our good fortune to enjoy at Flagstaff.

LOWELL OBSERVATORY, Flagstaff, Arizona.

1898, Feb. 16.

COMETS AND COMET FAMILIES. II.

W. W. PAYNE.

Last month a hasty review of Jupiter's family of comets was given under the above title, and, also a brief description of each of the two comet families belonging to the planets Saturn and Uranus. In reading the account, some disappointment may have come to the minds of those not acquainted with the subject of

comet families because of the small interest belonging to other families of comets as compared with that awakened in the case of the Jupiter family. Thought on this point will at once suggest the reason why a large number is counted in one family and small members make up all other existing planet families. The size of the planet Jupiter is greater than that of any other planet, Saturn being next in order. Jupiter's mean diameter is 86,500 miles while that of Saturn is 73,000 miles; but it should be noticed that the masses (amount of matter in each) is greatly different. If we measure the masses of these planets, by calling that of Earth unity, then the mass of Jupiter is 316, that of Saturn is less than 95. That means it would require 316 Earths to equal Jupiter in quantity of matter, and that Saturn furnishes enough world-stuff to make about 95 Earths. The mass of the planet is one of the main elements of its capturing power in relation to comets. Another important factor in the same direction is the velocity of the planet in its orbit. This, at first sight, may seem unimportant because the velocity of Jupiter and Saturn in their orbits respectively are 8 miles and 6 miles per second, not a marked difference, but an important one when taken in connection with the motion of the solar system through space toward the constellation of Hercules and other less powerful influences tending in the same direction.

From the plate of last month it is apparent that the orbits of the two members of the Uranus family have their nearest points to the Sun in the same general direction as those of the Jupiter family already noticed.

The Neptune family ranks next in interest to that of Jupiter. Its number is six and almost every one is a comet of historical interest, and some of them have a remarkable record.

The Westphal comet is the first usually named in this family. It has a period of revolution of nearly 70 years; its perihelion is outside of Earth's orbit and its farthest distance from the Sun about 30 times as great as Earth's mean distance. This comet was discovered by C. H. Peters and in October, 1852, it was visible to the naked eye. By noticing the continuous portion of its path in the plate it will be seen that its relation to the Earth's orbit is such that it might be favorably observed. Only a small part of the comet's path is on the north side of the ecliptic as is shown by the short dashes that make the greater part of it.

Brorson's comet, 1845 V has a longer and a more elliptical path. Its most distant point from the Sun is 35 times as great as that of Earth's mean distance. It was discovered in July, 1845,

by Brorson and was visible for eight weeks. The inclination of its orbit to the ecliptic 19° 8′ and almost all of its path lies on the south side of the ecliptic. Like the last named comet only a small part of its path is north of the ecliptic, and that part of it nearest to the Sun. Its period of revolution around the Sun is about 75 years. Its second known visit to the Sun and to the neighborhood of the Earth should therefore be expected about the year 1922.

Comet Di Vico 1846 IV was discovered Feb. 20, 1846, by M. Di Vico, of Rome, and also independently found by George P. Bond, of Cambridge, Mass., Feb. 26, of the same year. It was observed until May 19, and an elliptical orbit of 76 years was first given to it. Later computions give a period of revolution of less than 74 years which will bring its next probable return in 1919.

The comet Pons-Brooks 1884 I. was first seen by Pons July 20, 1812, and in 1816 Encke determined its elliptical orbit. The comet was visible in the telescope ten weeks and could be seen by the naked eye as claimed by some observers, and its tail was two degrees long. Its orbit lies very nearly in the same direction from the Sun as that of Di Vico just above referred to. The comet has a double name because it was re-discovered by Brooks Sept. 2, 1883. It is placed in the catalogues as comet 1884 I. because its date of passage of perihelion point of orbit came first in the year 1884. At this return the comet was visible nine months. Its perihelion point is within the Earth's orbit, and about three-fourths of its path is on the north side of the ecliptic.

In this particular the comet differs greatly from any of the three comets described which belong to the family. Its period of revolution around the Sun is now thought to be 70.68 years. It next return will probably be in 1954. This comet showed interesting physical characteristics during times of visibility in 1812 and in 1883. When first seen its form was irregular and nebulous. In 1883, as observed by Dr. Chandler in this country and Schiaparelli, of Italy, on several occasions, it would appear nebulous and soon change to a star-like form and then back again to diffuse nebulosity. The variation of these curious changes as noticed by Müller at Potsdam, Jan. 1, 1884 were as great as $\frac{7}{10}$ of a magnitude in brightness in less than two hours. From Jan. 13 to 18, no activity was especially noticeable in light changes, but on Jan. 19, the appearance of the nucleus had so changed that it was "difficult to realize" it as the same comet. The head now showed three zones of definite outline, which were well de-

scribed by Trépied as follows: "The interior and brilliant one was almost circular and remarkable owing to its milky aspect; it stood out sharply from the adjoining zone and was of a leaden hue, outside this second zone came the ordinary nebulosity of the tail having on the south-west side a parabolic outline."

"The nucleus had undergone considerable lengthening; it consisted of two distinct parts of very different brilliancy united by a very well marked twisted link which occupied almost the center of the inner circular zone. The southern part of the nucleus, which was by far the brightest, was terminated by an elliptical arc very sharply defined and tangential to the circumference of the zone; the northern part on the contrary was suddenly cut off at the extremity of the diameter whose direction coincided with that of the axis of the nucleus. This direction was almost exactly identical with that of the axis of the nucleus. On Jan. 20, the nucleus and nebulosity which surrounded it had resumed their accustomed aspect. I observed the comet up till the end of the first week of February without being able to detect any changes like those which happened on Jan. 19. It follows therefore that the transformations in question must have run their course in a few hours, and herein consists the remarkable character of the whole phenomena."

The observations above given were in general accord with those of Thollon, Rayet and Perrotin bearing date Jan. 13, which suggests that these wonderful changes were periodic in nature, and doubtless of the same kind as those of later comets which have aroused great interest among astronomers everywhere, in regard to the forces or the condition of cometary substance that could produce them.

Comet 1887 V, known as the comet of Olbers was discovered April 25, 1815. Bessel computed its orbit anticipating the planetary disturbance that the comet would suffer in its next journey, and claimed that it would again reach its nearest point to the Sun in 1887, February 2, giving a period of revolution of about 72 years. At its next return Professor Brooks of Red House Observatory, Phelps, New York, re-discovered it Aug. 24, 1887, and Ginzel computed its orbit showing that it passed nearest point to the Sun, October 8 of the same year. At its first appearance it was visible 25 weeks, at the last apparition it was in sight only eight weeks. Its perihelion point of path is outside of the Earth's orbit about twenty millions of miles. There was not much of special interest interest in the physical characteristics of this comet.

Halley's comet, the last of this family is one of great interest. This notable comet is possibly traceable to a time near the beginning of the Christian era. In 1680 Sir Isaac Newton published the Principia which furnished a method for computing the orbit of a comet dependent on three observations of the place of the comet, as related to the places of neighboring well-known stars, and on the theory of gravitation. By this method the illustrious Halley determined the orbit of this great comet of Jan., 1683, to be about 75½ years. In examining the earlier records of famous comets he concluded that there had been at least two returns before this time, in 1531 and in 1607, respectively, although the different periods were not quite uniform in length of time. At this early time, when so little was known about the methods of computation in regard to the disturbance of comets by planetary attraction, it was remarkable that Halley should have foreseen the real cause of the different lengths of the periods above referred to. In tracing the path of the comet between 1607 and 1682 Halley found that it passed so near Jupiter that its velocity must have been considerably increased, and that its period of revolution was correspondingly changed. In view of these facts he said that the next appearance of this comet would be in the last part of 1758 or the beginning of 1759, and if it should happen that this prediction came true, "an impartial posterity would not refuse to acknowledge that this was first discovered by an Englishman." Halley did not live to see his prediction fulfilled, yet as the time approached, very great interest was felt about it among astronomers, especially because Clairaut had predicted April 13, 1759, as the time when the comet would reach its perihelion. It was first seen on Christmas day 1758 and passed its perihelion point March 12. By looking at the chart again and noticing the dotted portions of the comet's path it will be seen that this comet, like all others of the family but one, lies very largely on the south side of the ecliptic and hence observations in northern latitudes could not be expected to last long. The comet was seen during the months of April and May in Europe, but, by far at the best advantage in the southern hemisphere. On May 5, at this appearance, the comet's tail was 47° long.

When the time for the re-appearance of the comet of Halley again was approaching attention was drawn to this notable visitor, and suitable preparations made for a scientific reception. In the mean time physical astronomy had made much progress, methods of computation had been simplified, many learned societies had been established, high prizes for better mathematical

methods of work had been offered, and the orbit of the Halley comet received first attention in the zeal of scholarly men in quest of knowledge of Nature's noble laws.

The problem of determining definitely the orbit of this great comet engaged the attention of the best scholars of the time, working in different ways, and obtaining results in several cases before the appearance of the comet, in others not until after its re-discovery. The results found for the perihelion time by the different computers were nearly the same, ranging within a period of 27 days. The ephemeris for the period of visibility and its exact path among the stars was published and on the 5th day of August, 1835, the Director of the Observatory of the Roman College, at Rome, directed his telescope to the place in the sky shown by the calculations, and found the comet apparently a "faint and almost invisible stain" of light on the deep blue of the heavens within one degree of its predicted place. This was a triumph for figures and mathematical ingenuity which gave much comfort and courage to workers in the starry fields. It seems incredible now that it is possible for the students of the stars to follow faint wisps of light till they totally disappear in one part of the sky and still know that they are travelling exactly in the direction of certain stars, and after seventy-five years, turn the telescope again in another direction and expect to find that same little stain of light lost to sight and telescope for three-fourths of a century in the starry depths coming back again to its appointed place, at the appointed time within an error of a few days only. If we remember, in regard to this comet, that it has travelled 35 times as great a distance into space as our Sun is from the Earth, which would send it 465 millions of miles beyond the farthest planet known to the solar system, the reader will get some little idea of the problems which the scholars of these and preceding years had been solving with purpose and masterful courage.

At another time we will say more about the physical characteristics of the comet of Halley as seen in 1835, something about the family of a possible unknown planet beyond Neptune, and also something about the nature and constitution of comets in general.

ON A CONSTRUCTION FOR THE GRAPHICAL COMPUTATION OF THE OCCULTATIONS OF STAR CLUSTERS.

WM. E SPERRA.

For Popular Astronomy.

As the Moon with its silvery index finger marks out the days and weeks and months by passing around that magnificent celestial dial, the starry heavens, it frequently happens that it passes over some of the brighter stars, and nearly every night some of the fainter stars may be seen to disappear behind the Moon's advancing disc. Then again it often happens that there are special configurations or groups of stars which the Moon in its monthly course occults, giving in the space of an hour or two several instances of this sublime phenomenon.

Who that ever witnessed a disappearance behind the dark limb of the Moon, will ever forget the thrill of admiration that flashed o'er his being while at the eye end of the telescope, he gazed upon a picture more beautiful than human genius ever conceived or human art ever constructed. There was Luna with every feature of her fair face clean and sharp cut as a coin just from the mint, and just a short distance away was a shining, twinkling, flashing jewel, more gorgeous than ever graced the brow of human monarch. And how with breathless expectation the observer watched the narrow chasm between Moon and star diminishing! In the height of admiration daring scarcely to breathe lest some of the beauty of the sublime spectacle would be lost. But while thus enraptured, with a suddenness that startles and bewilders the observer, the beautiful jewel that was set as a diadem upon the Moon's silvery brow is gone, and our pale satellite serene and calm sails alone in yonder sky.

But with whatever degree of ecstasy this sublime spectacle may inspire the observer, his interest in it will be greatly increased by knowing beforehand the hour and minute and the point on the Moon's disc where the star will disappear. Then when at the anticipated moment and designated place the star actually disappears, the observer is not only filled with admiration because of the beauty of the view, but is also filled with reverence and awe that man, a transient being, has been enabled to so understand the immutable laws of Nature as to point out in the distant future the time and place when so magnificent a picture would be hung in the azure vault of heaven for the gaze of man-

kind. But put in the hands of the amateur observer himself the method or means of determining this time and place and the aspect of the event, and his ecstasy will know no bounds when he sees in yonder sky the fulfillment of his expectations.

Two methods for computing the times of the occultations of the individual stars of a cluster by a graphical process from the data given in the American ephemeris have been described in the pages of this magazine: viz. in No. 14 pp. 176-181, and No. 28 pp. 414-425. The first method illustrates with great elegance the effect of parallax on the Moon's motion from hour to hour and the causes affecting the same. But as every element that enters into the construction depends on variable data owing to the varying distance of the Moon from the Earth; and, furthermore, the data required is of such a nature that some little labor is involved in collecting it from various parts of the ephemeris and preparing the construction from it, and besides it must be computed anew for each construction, there being no elements that can be carried from one construction to another. In the second method many of the elements can be computed once for all as they remain the same for all constructions for the same latitude, and, moreover, some of the data are found in the ephemeris in shape without further preparation for immediate use in the drawing, so that the labor in computing by this method is lighter than in the first. But the transference of the projection of the Moon's motion from what it is when viewed from the star to that as it appears from a moving point on the Earth's surface is awkward and not destined to give the student a clear conception of the causes affecting the Moon's parallax and consequently its apparent motion, though its apparent path will necessarily be the same by both methods.

If now some method can be devised which will illustrate with the elegance of the first method the effect of parallax on the Moon's motion, and yet retain the simplicity of computation of the second method two stocks of corn will have been made to grow where one formerly stood. From the use of the two methods above mentioned, such a process has been suggested to the mind of the writer and for several years satisfactorily used. To describe and illustrate by an example the use of such a method is the object of this paper. As some of the points of this method are common to the other two, it will be well if not already familiar with them, to read the matter in Nos. 14 and 25—28 of this magazine.

The fundamental idea of this construction is a projection of the

Earth and parallel of latitude of the place of observation on a plane perpendicular to the line connecting the centers of the Earth and Moon. One half of the Earth is always above this plane [Fig. 1] and turned toward the Moon. The figure represents the observer as situated below this plane to the east and a little north of the position of the Earth in the plane; this is why the intersection of the Earth by the plane appears as the ellipse whose center is *G*. The projection *JKH* on this plane of the parallel of latitude *LIM* will represent the path described by the place of observation due to the rotation of the Earth. If now an infinite number of lines be drawn from the intersection of the Earth and plane, and also from the ellipse representing the parallel of latitude to the center of the Moon and produced to the region of the stars, another figure similar to the projection of the Earth on the plane will be formed in the sky, but with the parts in an inverse direction. This figure represents the difference in the direction of the center of the Moon as seen from various points on the Earth, or in other words it is the displacement due to parallax, and the angular semidiameter of the circle* is the horizontal parallax of the Moon. Since the center of the Moon as regards the projection of the Earth on the plane is always in the line *CG*, and as the latitude ellipse represents the path of a place due to the rotation of the Earth, if any point on this ellipse *LIM* be connected by a line with the center of the Moon and this line be extended to the figure in the sky, and if further this point or end of the line moves with the rotation of the Earth, the terminus of this line on the figure in the sky will always show the parallactic position of the Moon's center for any moment of time, and this ellipse described on the face of the sky will be the

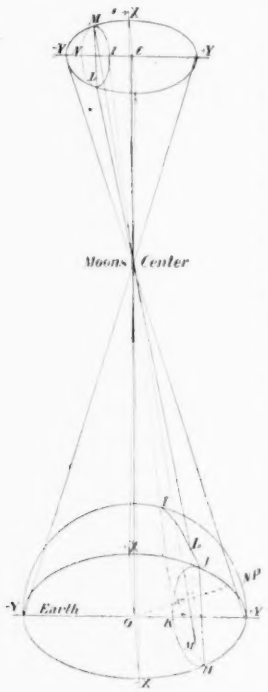


FIG. 1.

* As viewed from any point of the Earth it is a circle, but our diagram shows it as an ellipse owing to the point from which it is viewed. Figure 2 shows the same as a circle. The lettering of both figures is the same.

parallactic path of the Moon for each twenty-four hours of time. If the Moon and Earth had no linear motion, this ellipse would be fixed in the sky, that is as regards the stars. But as this is not the case the apparent path of the Moon which we will attempt to map is a composition of this parallactic path and its linear path due to the combined motion of the Moon and Earth considered for our purpose as one.

This parallactic figure in the sky is what will concern us in our construction. We will now proceed to show how to construct and use this figure and the data to be obtained from the ephemris so as to map the Moon's apparent path on the face of the sky. It will be noticed that in the method described in Nos. 25 to 28 of this magazine, a plane has been used called the fundamental plane, and some of the quantities given in the ephemris and made use of in the construction are derived for this plane. Now we have referred to a plane which is not altogether coincident with this fundamental plane, the perpendiculars to these planes make with each other an angle equal to the angular distance between the Moon and our reference star. As the construction is referred to the time of conjunction in R. A., the difference is equal to the difference in Decl., and is so small that for this method of computation we may consider them coincident planes and make use of the quantities calculated for the one in the other without vitiating our results in the least.

The data required for the construction are:

1. Longitude and geocentric latitude of the place for which the construction is made.
2. R. A. and Decl. of some central star of the group to be occulted, and referred to as a reference star.
3. Local mean time of transit of the reference star.
4. Local mean time of geocentric conjunction of Moon and star.
5. Local hour angle of the star at geocentric conjunction.
6. Moon's declination.
7. Moon's hourly rate in the coördinates X and Y.
8. Moon's semi-diameter.
9. Scale $1^\circ = 980''.17 \div$ Moon's semi-diameter.

(1), (2) and (3) of the above will no doubt be clear to all without comment. (4) is obtained by algebraically adding the longitude (considered + if east and — if west) from Washington to the time in the column on the right of the heavy central line of the tables of elements for the prediction of occultations given in the ephemeris. [Unless otherwise stated all references are to these tables.] (5) is obtained in exactly the same way from the next column. (6) is taken out for the moment of geocentric conjunction from the monthly tables of the Moon's R. A. and Decl. for every hour of Greenwich time. (7) is given in the columns x' and

y' opposite the star. (8) must be taken from table IV of the monthly calendar for Greenwich.

In the construction and in the projection of the Earth on the plane, we make use of the usual X and Y axes. These axes intersect at the center of the Earth, and the X axis passes through the points of intersection of the plane and equator; the other is at right angles to this one and passes through the north and south points of our diagram. These coördinates are positive to the north and east of their intersection and negative on the other side, whether either of the figures is referred to. In order to locate at a given time any point upon *JKH* the projection of the circle of latitude *LIM* on the plane, we make use of the following formulæ, where

φ' is the geocentric latitude of the place.
a is the semi major axis of ellipse.
b is the semi-minor axis of ellipse.
d is the distance of the major axis of the ellipse from X
τ is the hour angle of the place from Y
ξ is the horizontal distance of place from Y
η is the vertical distance from the axis of X
δ is the Moon's declination.

Let the radius of the Earth be designated by unity, then

A. $a = \cos \varphi'$
B. $b = \cos \varphi' \sin \delta$
C. $d = \sin \varphi' \cos \delta$
D. $\xi = \cos \varphi' \sin \tau$
E. Distance of place from $a = \cos \varphi' \sin \delta \cos \tau$
F. $\eta = \sin \varphi' \cos \delta - \cos \varphi' \sin \delta \cos \tau$
G. Points of tangency with the Earth's disc $= \sin \varphi' \sec \delta$

For the projection of the center of the Moon on the ellipse formed in the sky as the result of parallax, these formulæ remain true. As already stated the signs of X and Y coördinates remain $+$ and $-$ in the same directions as in the diagram of the Earth, while the signs of the angle τ becomes reversed in direction, the latter as the result of the inversed order of the diagram; why the former do not change will be clear later on.

As no good occultation of a cluster visible from the United States will occur any more this year, and as an example to illustrate the method, I will take that of the Pleiades observed here on August 19, 1897. First in order will be the collection of the necessary data. For (1) we have longitude west of Washington $16^m.7$, and latitude north $41° 3'$ from which subtract $11'.5$ for the geocentric latitude. For (2) we obtain $\alpha = 3^h\ 41^m\ 24^s.8$, δ, $23°\ 47'\ 25''$. For (3) we have $17^h\ 45^m\ 13^s.6$. For (4) we get $17^h\ 35^m.3$. For (5) we find $-13^m.0$. From page 154 of the Ephemeris we find that (6) is $24°\ 36'\ 25''.5$. From page 441 under

the columns x' and y' we find that the Moon's hourly rate in the two coördinates is .535 in X, and + 0.106 in Y. From page 131 we get from the Moon's semi-diameter 14′ 48″.6. (9) then becomes $1° = 1.103$.

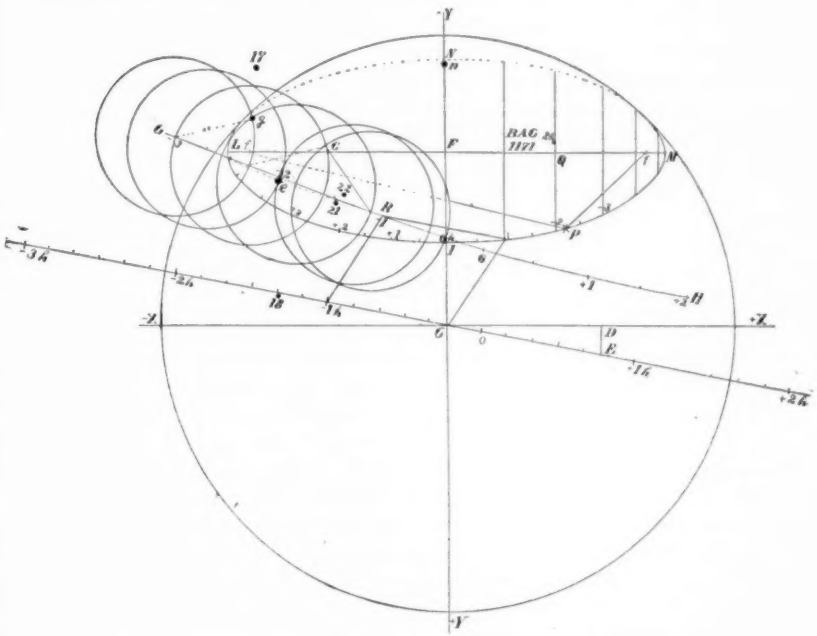


FIG. 2.—PATH OF THE MOON THROUGH THE PLEIADES AUG. 19, 1897.

In constructing our diagram [Figure 2] I use a millimeter plotting scale, and draw the large circle with a radius of 100*mm*, though any other decimal scale will do as well, but the radius of the circle must be considered as unity. The semi-major axis of the ellipse will then be equal to the natural cosine of the geocentric latitude, in this case it is .756; and formula *C* gives .595 as its distance from the axis of X, and as our latitude is north this distance must be taken to the south or on $-Y$. The major axis the ellipse is, of course, drawn parallel to X. Formula *B* gives .315 for the semi-minor axis; we lay off this distance on Y on either side of its intersection with the major axis. Having the axes of the ellipse we can draw it with an ellipsograph, or in the absence of such an instrument in one of the following ways: By formulæ *D* and *E* the distance of points on the ellipse from both axes are computed for every 15° of time. It will be well to com-

pute τ for every ten minutes of time for use later on. The quantities resulting from formula D will be the same for all constructions for the same latitude, but those of E will change owing to the varying declination of the Moon. The log. for the product of $\cos \varphi' \cos \tau$ can be entered on a slip of paper and kept, as it will only be necessary to add the log. of $\sin \delta$ for the log. of the required product. The points for our present ellipse from the use of the above formulæ are:

τ	$\cos \varphi' \sin \tau$	$\cos \varphi' \sin \delta \cos \tau$
15°	.196	.304
30	.378	.266
45	.535	.223
60	.655	.158
75	.731	.082

Since the sum of the distances of any point P from the foci of the ellipse is equal to the major axis, a more convenient method and one which dispenses with the quantities of formula E is as follows: With either extremity of the minor axis as a center and a radius equal to a draw arcs intersecting LM in f and f, these points are the foci of the ellipse. Take any point as Q in the major axis LM, then with the foci as centers, and radii equal to LQ and MQ draw intersecting arcs as at P; four points upon the ellipse may thus be found. By taking other points in LM, a number of points in the arc of the ellipse may be quickly laid off, and a smooth curve drawn through them which will be the ellipse required. The hour points may be found by means of the quantities of formula D, which are marked off on the major axis and perpendiculars intersecting the circumference of the ellipse, erected at the points.

Having now drawn the ellipse and found the hour points, these we number to the west of the meridian or Y axis, $+ 1^h$, $+ 2^h$, $+ 3^h$, etc., and in a similar manner we number those east of the meridian with the negative sign.

The path of the Moon as seen from the center of the Earth is next laid off by means of the quantities under (7) as follows: Lay off on $+ X$ from C a distance CD equal to .535, and at D erect the perpendicular DE in $+$ or $-$ Y as the case may be, equal to $+ 0.106$. Draw a straight line AB through C and E to represent the path of the moon as seen at the center of the Earth, and CE will be the distance the Moon moves in an hour. The quantities x' and y' have been computed on the hypothesis that the observer is placed on the star and watching the Moon pass across the disc of the Earth. But since the diagram we are constructing is the parallactic representation of the Earth, the same ratio

and direction of its motion will be true for our diagram as for the case for which they were computed, therefore X must be positive toward the east in both cases.

It will now be necessary to locate the Moon on its path AB at the moment of transit of the reference star. From (5) we find that its hour angle at geocentric conjunction is -13^m, therefore the Moon and star when at conjunction are at 13^m east of the meridian of Randolph, therefore take on CE a distance equal to 13/60 of CE and call this Oh; then this represents the geocentric position of the Moon with reference to the star when the latter is on the meridian of Randolph. With this point as a starting place AB* should be graduated for every ten minutes of time; these points will represent the position of the Moon in hour angles of our reference star, and they should be marked + after the Moon passes Oh.

As we have already stated the apparent path GH is a composition of the parallactic path $LIMN$ and the path AB, therefore to lay off any point on GH as $-lh$, take a compass and with radii equal to C to $-lh$ on ellipse and from C to $-lh$ and AB, with $-lh$ on ellipse and $-lh$ on AB as centers describe intersecting arcs at R. R is then the point $-lh$ on GH, the other points may be laid off in a similar manner and the curve GH drawn through them. Please notice that a parallelogram is formed. By marking on the ellipse our ten minute points previously computed, with those on AB, we can locate the ten minute points on GH.

This done we are ready to plot the stars of our cluster, and to do this we make use of (9). The 980″.17 is obtained thus: the ratio of the Moon's semidiameter to that of the Earth is .27227, and assuming that 1° = unity or the radius of our diagram, the Moon's angular semidiameter then equals 980″.17, but this is not always true as the Moon's semidiameter is a variable quantity, therefore 980″.17 is divided by the real semidiameter, this gives the true value of 1° in the radius of our diagram.

Since the elements of our diagram are taken out for the moment of geocentric conjunction in R. A., our reference star must be plotted on the Y axis, at a distance from C equal to 49/60 of 1.103 = .901, to be taken in this case on $-Y$ as the Moon is 49′ north of the star. Having now placed the reference star, the places of the other stars may be located by means of their position angles and angular distances reduced as above to the units of a diagram. If the position angles and distances are unknown, they can be obtained as follows: On pages 418-421 of the ephem-

* This lettering was accidentally omitted from copy and so does not appear in cut.

eris are given the mean places of the stars occulted by the Moon; from this list take out the differences in Decl. and and R. A. of the reference star of the cluster and the others. Multiply the difference in R. A. by the cosine of the star's Decl. to reduce the arc of a great circle. Reduce these differences in R. A. and Decl. to the decimal of a degree; then plot on a scale in which one degree equals the radius of our diagram, then with a protractor and scale carefully read off the angles and distances. These can be preserved for future use, as it is only necessary to multiply the distances by the scale to adapt them to any construction.

To quickly lay off the position angles the following device can be used: Take a piece of heavy drawing paper large enough to include all the stars of the cluster, and make a pinhole at its center to indicate the position of the reference star, then mark off the position angles and distances of the other stars; slots can then be cut in the line of the angle and sufficiently long on either side of the star's distance to allow of the contraction and expansion of our scale, the distance can then be quickly located. If some other star than the central one of the group be used as the reference star, the central star can be plotted from the reference star, and then the others plotted from the central one as above.

The stars plotted, to find the times of immersion and emersion, open a pair of dividers to .272, the ratio of the Moon's disc to that of the diagram; with the star for which the times are desired as a center describe two arcs intersecting *GH* in two places, the position of these will indicate the times of immersion and emersion in the hour angle of the reference star. It is the sidereal hour angle which must be reduced to solar hour angle and added with its proper sign to the time of transit of the reference star, this sum will then be the time required. For instance take 19 Tauri the arcs give $-2^h\ 41^m$ and $-1^h\ 16^m$ in the hour angle of η Tauri, which reduced to solar time and algebraically added to the time of transit of η, give as the time of immersion and emersion $15^h\ 4^m\ 40^s$ and $16^h\ 29^m\ 25^s$ respectively. The observed times were $15^h\ 5^m\ 34^s$ and $16^h\ 29^m\ 22^s$.

If the position angles are desired, a circle to represent the disc of the Moon can be drawn with its center at the place where the arc intersects *GH*, and the angle read off with a protractor.

Below are appended the position angles and distances of the brighter stars of the Pleiades obtained by the method given above. The distances are in the units of our scale.

	°	d
g Pleiadum	286.2	0.638
b 17 Tauri	270.4	0.595
18 Tauri	323.8	0.904
e 19 Tauri	304.3	0.636
c 20 Tauri	304.3	0.464
21 Tauri	321.6	0.570
22 Tauri	321.5	0.534
d 23 Tauri	238.5	0.304
24 Tauri	292.4(?)	0.024
η Tauri	0.0	0.000
B.A.C. 1171	43.3	0.333
26 Tauri	53.5	0.415
f 27 Tauri	97.2	0.388
h 28 Tauri	84.7	0.394

1898, March 8,
Randolph, Ohio.

DUNER AND SCHEINER ON STELLAR EVOLUTION.*

In conclusion the author explains his views on stellar evolution. It is evident that these must depend on the theory taken as a starting point. He therefore states first his views in regard to the two latest solar theories, Lockyer's Meteoritic Hypothesis and Schmidt's Gas Theory. Concerning the first, he has stated his position so clearly in his "Spectrum Analysis of the Stars" that no one could consider him as one of its adherents. But in regard to Schmidt's theory, while recognizing its theoretical truth, yet he is persuaded that, even if the possibility of a condition assumed by the theory cannot be disproved, it does not really exist in the Sun or those stars whose spectra have been accurately investigated.

The author, in common with most astronomers, consider each star as a glowing sphere of gas, having at a certain distance from the center a photosphere, composed essentially of products of condensation. These originate from one or more elements for which a state of saturation exists at a certain height in the hydrogen atmosphere, exactly as clouds are formed in the earth's atmos-

* Extract from the *Vierteljahrsschrift*, Vol. 32, part 3.

No. 26 of the Publications of the Astrophysical Observatory of Potsdam is entitled "Investigations of the Spectra of the Brighter Stars by Photography," by Professor J. Scheiner. Taking the spectrograms made with the 12-inch Potsdam refractor for the special purpose of determining the motions of the brighter stars in the line of sight, Professor Scheiner has investigated them to secure their testimony as to the composition and condition of the stars in question. Vol. 32, part 3 of the *Vierteljahrsschrift der Astronomischen Gesellschaft* contains an excellent review by Dr. N. C. Dunér, of Upsala, of Scheiner's work. The latter part of this I have translated, as presenting the latest statement by the highest living authorities, of the theory of stellar evolution, as revealed by the spectroscope.

J. A. PARKHURST.

phere from moisture carried by ascending currents. In opposition to the views generally held, the author considers the assumption necessary, that within the outer layers of the photosphere the gases must exist in a state of extreme rarity. The density of the condensation-products is therefore comparable with the most delicate cloud formations in the highest regions of our atmosphere. The star is at first enveloped in an extensive atmosphere of hydrogen, whose spectral lines appear very strong and dark, unless the atmosphere attain such a height that the lines are illuminated,* nearly invisible or even bright. The metallic lines, on the contrary, are very weak or invisible at this stage of development, from the high temperature of the absorbing layer. On account of rapid radiation there follows a contraction which balances the loss of heat, especially in the interior of the star, but there is a decrease in the volume, not only of the inner sphere of gas but also of the atmosphere. In consequence of the lessened height of the latter, the fall in temperature becomes more rapid and the absorbing layer becomes cooler. Metallic lines, and in some stars helium lines, then show more clearly in the spectrum.

With the continued cooling of the star a marked change takes place. While the metallic lines become stronger and more numerous, the hydrogen lines become much weaker than at first, so that they are exceeded in breadth and intensity by certain metallic lines. The author seeks for the cause of this change partly in a direct loss of hydrogen from the atmosphere into space, and partly (as it seems to the reviewer, principally) in phenomena which are direct consequences of contraction. For instance, as the diameter of the star and with it the hydrogen atmosphere, decreases, the previously formed photosphere sinks towards the center. Further condensations occur in the cooler atmosphere above, and thus the upper limit of the photosphere approaches the upper limit of the atmosphere. The absorbing layer of hydrogen therefore becomes thinner, and the hydrogen lines less broad, finally no stronger than the most prominent metallic lines. The

* The significance of the term "aufgehellt," translated "illuminated," is explained as follows by the author on page 177. "Since in all spectra belonging strictly to Class I, the hydrogen lines are much broader than in the solar spectrum, it must be assumed that these stars have immense hydrogen atmospheres. But if the height of this atmosphere is small in proportion to the radius of the star, it will make itself known by absorption rather than by radiation of light. The lines will therefore appear dark, and the darkness will be most intense in the middle. If the relative height of the hydrogen atmosphere is greater, it will make itself known by emission as well as by absorption, and the lines will be illuminated (aufgehellt) in the middle; and finally if the height becomes considerable, the hydrogen spectrum will appear with bright lines, perhaps bounded on each side by the remnants of the dark absorption lines, or, if the height is still greater, superposed directly on the continuous spectrum."

star has then passed to Class II*a*. As the cooling proceeds still further so that chemical combinations can take place in the atmosphere, the star passes into Class III. Whether the photospheres of the stars of Classes II*a* and III*a* are really cooler than those of Class I*a*, must remain unsettled, as it cannot be distinguished whether the weakness of the violet end of the spectrum arises from a lower degree of incandescence of the photosphere, or a stronger absorption in the atmosphere.

In the judgment of the reviewer, there can be no doubt of the general correctness of these views. He must only express his decided opinion that the weakness of the violet part of the spectrum in Classes II*a* and III*a*, always, or at least generally, arises from absorption in the atmosphere of the star. The spectrum of an ordinary incandescent light is relatively rich in violet rays, and if that weakness of light is caused by a lower temperature of the star, it must be assumed that it is no longer white hot. This is contradicted by the estimates which the author makes of the temperature of the absorbing layer. As this reaches 3000° or 4000° even in stars of Class III*a*, the still hotter photosphere must glow with the most intense white heat and send out rays of every refrangibility.

With regard to the structure of the photosphere, the reviewer agrees more nearly than the author, with the commonly accepted theory. With him he considers the upper layer of the photosphere to be comparable with the most delicate cloud-formations in our atmosphere. This is sufficiently proved by the character of the spectral lines. But I do not think that one such stratum can form the photosphere. If we consider the enormous radiation of heat from a star, it is evident that these extremely rare clouds are not sufficient to supply it. They must quickly become denser and sink to lower strata of the gaseous sphere, in a condition reminding us of snow or rain, only to be again vaporized, partly by the fall and partly by absorption of heat from the surrounding gases. This in turn will cool and condense the surrounding material, whose products, from their position, will be of greater density than the original clouds. The radiation from these denser clouds will be very considerable and will contribute powerfully to the maintenance of the high temperature and radiating power of the upper clouds. They will thus become cooler and sink, as denser condensation products, into still lower strata. These alternations will continue and maintain the radiating power of the star.

At first, while the condensations take place in very hot gases,

the chemical composition of the photosphere will be quite simple, consisting perhaps of but one or two elements, which have the lowest melting points. At that time the photosphere will be the rarest, as even the very hot gases in which the clouds float, will contribute powerfully to restore the lost heat. The cooler the gases, that is the nearer the star approaches Class II or III, the greater the number of elements which can condense to photospheric clouds, and the denser they will be. This will permit chemical combinations in the absorbing layer of the star. It is evident that the elements which condense at the lowest temperature will form the outer layer of the photosphere. The absorbing layer, lying without or partly within these clouds, will be protected by them from immediate contact with the hot clouds of the photosphere, so that chemical combinations can take place and be maintained. If this analysis is correct, the question whether the photospheres of the different classes are at different temperatures, must be answered in the affirmative. I remark finally, that I do not think that the author is opposed to this general conception of the photosphere, as consisting of various strata of different densities, though he has not touched directly upon the question. At any rate he only requires the "extraordinary rare condition" in the upper strata of the photosphere, which seems to prove that perhaps he recognizes an entirely different density in the lower strata.

The investigations of the author furnish a very strong support to Vogel's classification of stellar spectra. It is to be hoped that they may also contribute to the adoption of this only rational classification so that finally the Types*, to which astronomers have clung with a persistence worthy of a better cause, may disappear forever from astrophysical works. It is sad to think that a classification is still used, at the best of doubtful accuracy, for which it can only be claimed that it was proposed a few years before that of Vogel, when the science of astrophysics was in its earliest stage, and it was not yet possible to form a rational classification.

PETURBATIONS OF THE HEAVENLY BODIES.

F. R. MOULTON.

FOR POPULAR ASTRONOMY.

The readers of POPULAR ASTRONOMY are familiar with the fact that if there were but one planet revolving around the Sun its orbit would be strictly an ellipse, and its position at any time

* Duner evidently refers to Secchi's "Types."

past or future could be easily determined. But as there are several bodies, each one attracting every other, this simple motion is not realized. These deviations from the true elliptical motion caused by the mutual action of the planets are called *perturbations*. A knowledge of their magnitudes and character is necessary for the determination of the positions of the members of our system.

The practical value of the computation of these deviations is, that it enables us to fix the exact time of ancient eclipses and thus put on a solid foundation many of the fundamental points of chronology which would otherwise be in a hopeless tangle. Of more use still have been the tables of the positions of the Moon and Sun which have made possible the remarkable maritime activity of modern times. It is gratifying to the astronomer that he can take the great law of physical nature alone as his guide, and lead the historian back over recordless ages where mankind had lapsed into semi-barbarism and connect former civilizations with our own; and he feels a pride that he has had an important part in the material progress of the age. But more inspiring still, and that which has spurred him on to such great efforts, is the knowledge that he has within him the power of predicting for centuries the results of the almost immeasurable forces of nature; the knowledge of future events seems like actual experience to him and his life becomes multiplied in length, while he enjoys the calmness which comes from observing the workings of perfect law. It is not strange that many of the best minds from Kepler and Newton to Newcomb and Hill have devoted themselves to the study of the motions of the heavenly bodies.

The object of this paper will be to indicate something of the nature of these perturbations, and roughly how they are computed. It is hoped that those who have not had the opportunity for the requisite mathematical training to enable them to comprehend the beautiful researches of the great geometers on these subjects, but who are interested in the ways of nature will find the following explanations of value.

For convenience the discussion will be divided into two parts. First, a geometrical method of calculating the components of the disturbing force, and of determining with the help of the formulas of elliptical motion how the different elements are changed. The results can be understood by anyone familiar with geometry and the simplest properties of ellipses. Second, an explanation of the *method of the variation of the elements or parameters*. This most elegant conception of the nature of perturbations

and method of their calculation is due to Lagrange, and has been the most extensively employed of any in actual computations. An explicit statement of the mathematical features of the processes involved might be too abstract for a popular article so the essential characteristics will be illustrated by a very simple example. The philosophy of the whole process can be entirely comprehended by anyone who knows the elements of the integral calculus, and a large part of it can be understood by those who have not had even that much.

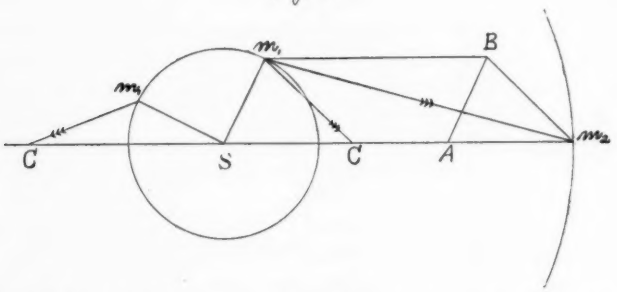
I. Geometrical Method.

While not implying that there is anything new in the results given it has seemed advisable to state each fact to be proved as a theorem, in order that it may be more clearly preceived just what point we are considering. Let us adopt the following notation:

a	denotes	the major semi-axis of the ellipse.
e	"	"	eccentricity of the orbit.
ϖ	"	"	longitude of the perihelion.
Ω	"	"	longitude of the ascending node.
i	"	"	inclination of plane of orbit to referenee plane.
v	"	"	longitude of the planet from perihelion.
V	"	"	velocity in the orbit.
μ	"	"	Sun's attraction at unit distance.
U	"	"	velocity falling from infinity.

If the planet moved around the sun and were not disturbed by any other bodies, it would move in an ellipse, and we shall consider how the elements of this ellipse are changed by external forces.

Fig. 1.



We shall first find the disturbing force geometrically and then resolve it into three components, (1) W, the component perpendicular to the plane of the orbit which we shall consider positive towards the north pole of the heavens; (2) T, the component in the direction of the tangent, positive in the direction of the motion;

(3) R, the component in the direction of the radius vector, positive when it tends to increase the radius.

Let the planets m_1 and m_2 be the two bodies considered moving around the Sun, S. We require the disturbing force of m_2 upon the motion of m_1 when m_1 has either of the positions indicated in the figure. Let the line $m_1\ m_2$ represent the attraction of m_2 upon m_1 in magnitude and direction. Then the attraction of m_2 upon S will be represented by SA. SA is smaller than $m_1\ m_2$ because m_2 is nearer (taking m_1 on the right) to m_1 than it is to S. By the parallelogram of forces $m_1\ m_2$ can be resolved into two components, m_1B and Bm_2, so that m_1B is parallel and equal to SA. Therefore the forces m_1B and SA being parallel and equal will not disturb the relative positions of S and m_1, hence Bm_2 or the equal and parallel force m_1C is the disturbing force on m_1 arising from the attraction of m_2.

This can be calculated numerically as follows: Since the attractions are inversely as the squares of the distances,

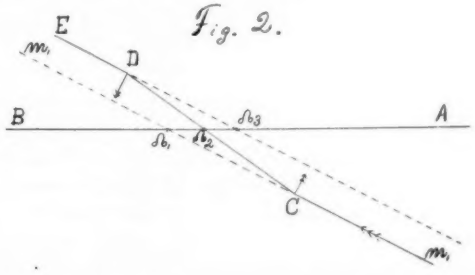
$$SA : m_1m_2 = \overline{m_1\ m_2}^2 : \overline{m_2\ S}^2 \quad \text{whence}$$

$$SA = \frac{\overline{m_1\ m_2}^3}{m_2S^2} = m_2C$$

Hence m_1C can be found by solving the triangle $m_2\ m_1C$ in which $m_2\ m_1$, m_2C and the angle $m_1\ m_2C$ are known. Now m_1C can be resolved into three components by the parallelopiped of forces. They are as defined above W, T and R and can be easily computed by very elementary methods.

Let us now consider the effect of W upon the line of nodes and the inclination of the plane of the orbit to the plane of reference. It will be noticed that as T and R act in the plane of the orbit they can have no effect on these two elements.

Fig. 2.



Let AB be the plane of reference. Suppose m_2 is in this plane,

then W will always be directed toward this plane. Let $m_1 m_1$ be a portion of the orbit that m_1 would describe if it were not disturbed by W.

Theorem I. When W is directed toward the refererence plane the nodes of the disturbed orbit regress on the reference plane.

For, supppose that W_1 is a small blow at C then m_1 will move in a new curve CD whose node, Ω_2, is back of that of $m_1 m_1$. Suppose that at D, W_2 is again a small blow, then m_1 will move in a new curve DE which extended backward is seen to have its node at Ω_3 which is also a regression. If these blows become infinitely close together we have the continuous disturbing force W and the theorem is proved. The result for other initial conditions is evident.

Theorem II. When W is directed toward the reference plane the inclination increases in the quadrant preceding the passage of the node, and decreases in the quadrant following the passage of the node.

This is evident from Fig. 2, and the opposite and related propositions follow in a similar manner.

Let us now consider the effect of T and suppose it always positive, that is, operating in the direction of motion. The opposite results will follow in every case when it is negative. If the motion of m_1 were undisturbed we should have the following relations which are easily found by calculus, and are given in such works as Young's General Astronomy.

$$r = \frac{a(1-e^2)}{1+e\cos v} \tag{1}$$

$$a = \frac{r}{2}\left(\frac{U^2}{U^2 - V^2}\right) \tag{2}$$

$$U^2 = \frac{2\mu}{r} \tag{3}$$

$$V^2 = \mu\left(\frac{2}{r} - \frac{1}{a}\right) \tag{4}$$

Theorem III. (*a*) *The component T at every part of the orbit increases the major axis;* (*b*) *in the neighborhood of the perihelion it increases the eccentricity, and in the neighborhood of the aphelion it decreases the eccentricity;* (*c*) *in the first half revolution it causes the perihelion point to advance and in the second half to regress.*

(*a*) If we suppose T to be a small blow in the direction of motion it will increase the velocity but will not change the r directed

that way. Then, since U^2 has a definite value at the point where the blow is struck, we see from formula (2) that a sudden increase in V will necessitate an increase in a at whatever part of the orbit the disturbance occurs. When the number of blows becomes indefinitely great we have such a disturbing force as occurs in nature. Practically, T will be found to be positive part of the revolution and negative or zero the remainder. Its sign must be determined from Fig. 1.

(*b*) Let us take $v = 0$ and then see what effect T has upon e. We have from formula (1)

$$r = \frac{a(1-e^2)}{1+e\cos(0)} = \frac{a(1-e^2)}{1+e} = a(1-e).$$

r is not changed but by (*a*) a is increased hence e must increase to preserve the equality of the expression. When $v = 90°$ we have

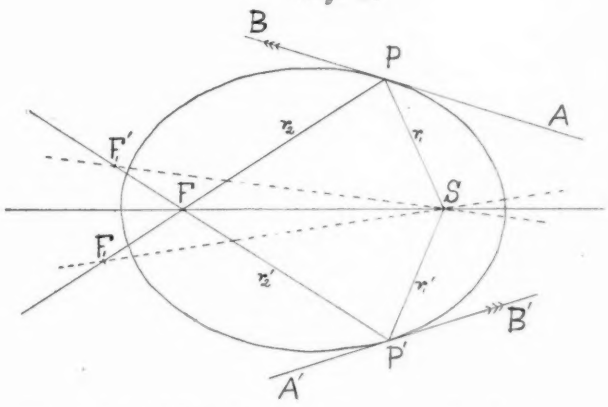
$$r = \frac{a(1-e^2)}{1+e\cos(90°)} = a(1-e^2)$$

Hence e still increases. The same holds for $v = 270°$. When $v = 180°$ we have

$$r = \frac{a(1-e^2)}{1+e\cos(180°)} = \frac{a(1-e^2)}{1-e} = a(1+e)$$

Hence at aphelion as a increases e must decrease.

Fig. 3.



(*c*) We need the following figure to prove the theorem concerning the longitude of the perihelion, or more simply the direction of the major axis.

S is the position of the Sun which is fixed. Now since the veloc-

ity and direction of motion at P are known the whole ellipse can be constructed. By formulas (3) and (2) a can be computed. Then it is known that if F is the other focus of the ellipse the angle BPF must equal the angle APS which has been found, hence the line PF can be drawn. Since $r_1 + r_2 = 2a$ and a is known the distance PF can be laid off which is sufficient to determine the whole ellipse.

Now to the part (*c*) of the theorem! r_1 is a given length and since by (*a*) a is increased we see from $r_1 + r_2 = 2a$ that r_2 must be increased, so that the focus is thrown down to some other point, F_1. The major axis has the direction F_1S which has rotated forward from FS. In the second half we find by similar reasoning that the major axis will retrograde to $F_1'S$. T has no effect on the direction of the major axis when it acts at the perihelion or the aphelion. A resisting medium is simply a negative T and the opposite of Theorem III is the qualitative solution of such a disturbance.

Theorem IV. (*a*) *The component R increases the major axis in the first half revolution and decreases it in the second;* (*b*) *it does not change the major axis when acting at perihelion or aphelion;* (*c*) *in the first half revolution it increases the eccentricity and decreases it in the second half;* (*d*) *in the neighborhood of the perihelion point it causes the major axis to rotate forward, and in the neighborhood of the aphelion, backward.*

(*a*) Since the body is receding from the Sun in the first half revolution the blow will increase its velocity. The opposite holds for the second half revolution. Hence by (2) a is increased in the first half and decreased in the second.

(*b*) Since the blow in the direction of the radius vector does not change the velocity at the perihelion and aphelion points, we see from (2) that it does not change a.

(*c*) When $v = 90°$ we have from (1)

$$r = \frac{a\,(1 - e^2)}{1 + e\cos\,(90°)} = a\,(1 - e^2)$$

Since a is increasing e must also increase to preserve the equality of the expression. When $v = 0$ or $180°$ a is not changed hence at those two positions e is constant also. It is evident that the sign of the variation of e does not change between $v = 0$ and $v = 180°$, hence e increases the whole first half revolution and similarly it can be shown that it decreases the whole second half.

(*d*) From Fig. 3, it is evident that the blow R will change the

direction of the motion PB outward, hence in order to keep the angles APS and BPF equal, PF will have to be rotated outward toward PF_1'. Since a increases, r_2 will have to be longer as in Theorem III (e), but it is a question in this case whether r_2 will be long enough so that F_1 will fall below the line FS or not. Since a small change in the direction of PF has more effect on whether F_1 will be above FS or not when P is near perihelion, and as near perihelion the change in a and consequently in r_2 is small, we may feel safe in concluding that for small valuss of v, F_1 will be above FS and consequently the perihelion point regresses while for large values of v the perihelion point will advance. The method of solution when the blow occurs in the second half is just the same. When the blows become infinitely near each other we have the continuous disturbing force.

There is another very interesting class of perturbations which effect the elements as would a change in the mass of the Sun. Let us therefore see what effect a change in μ will produce upon the elements.

Theorem V. (a) *An increase in* μ *occurring when the body is at any part of the orbit will cause a decrease in the major semi-axis;* (b) *it will cause the eccentricity to increase in the neighborhood of the perihelion and to decrease in the neighborhood of the aphelion;* (c) *it will cause the perihelion point to regress during the first half revolution and to advance during the second half.*

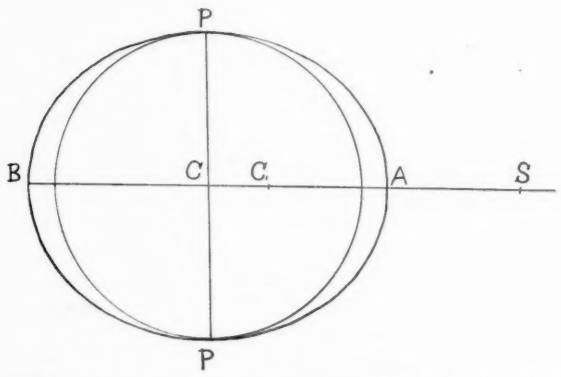
(a) A change in μ will not change the velocity and radius instantaneously, hence we see from formula (4) that when μ is increased a must be decreased to preserve the equality of the expression. (b) and (c) follow precisely as the opposites of Theorem III (b) and (c).

If we suppose that it takes gravitation a finite time to go from the Sun to a planet, it is easy to see that when the planet is receding from the Sun it is attracted *less* than it would be if gravitation were transmitted with infinite velocity, and *more* when approaching. To make the conclusion apparent it may be remarked that in the exaggerated case when the planet is receding faster than gravitation is propogated it will not be attracted at all, for the gravitational influence will not be able to overtake it. Hence when the planet is making its first half revolution, or receding from the Sun its orbit is effected as though μ were decreased and in the second half when it is approaching the Sun as though μ were increased. Hence we see by Theorem V (c) and its opposite that the perihelion point will continually advance. The greater the eccentricity the greater will the change in μ be, and conse-

quently the more rapidly will the direction of the major axis vary. Since the orbit of Mercury is much more eccentric than that of any other planet its perihelion point will advance much more rapidly than the perihelia of the others as Dr. Laves pointed out in the February number of POPULAR ASTRONOMY. It should be remembered that our discussion of this source of variation in the elements is far from being complete.

We shall now show that if a satellite revolves around an oblate planet in the plane of its equator, there will be a forward rotation of the major axis.

Fig. 4.



Let *APBPA* be a meridional section of the oblate planet with the satellite at *S*. If the planet were a sphere it would attract the satellite as though its whole mass were concentrated at *C*. But, being an oblate spheroid it will attract *S* as thongh its whole mass were at C_1. As *S* recedes from the planet C_1 approaches *C*. For example, the Earth is so far from Jupiter that his attraction upon our planet is sensibly the same as though he were a perfect sphere. That is, C_1 and *C* very nearly coincide. But for a satellite revolving very near Jupiter this is not the case. Now if the satellite is moving in an elliptical orbit about the planet, it is receding in its motion during the first half revolution. Consequently the attraction of the planet has decreased more than it would if it had been a sphere, and so far as the motion of the satellite is concerned we may assume that the mass of the planet has decreased. During the second half we would have to assume that the mass had increased. Then by applying the osposite and direct statements of Theorem *V* (*c*) in the first and second half

revolutions respectively, we see that the equatorial bulge will always cause a direct rotation of the major axis.

The amount of this evidently depends upon three things, the oblateness of the planet, the nearness of the satellite and the eccentricity of its orbit. The most favorable case in the solar system for a large motion of this sort would be the fifth satellite of Jupiter, and calculation has shown that the line of apsides advances more than two whole revolutions in a year.

We have shown how the components of the disturbing force can be computed by very simple methods, and how to determine what effect each will have upon the different elements. The theorems given above at once furnish the answer to questions such as that proposed by Mr. W. H. S. Monck in the February number of POPULAR ASTRONOMY. It may be stated that many indirect consequences have been omitted. Since the components vary with the changing positions of the planets in a complex manner it is impossible to determine quantitatively with any very great degree of accuracy by geometrical methods how much the elements will change in a given interval of time. For quantitative work the formulas of analysis must be used.

II. METHOD OF VARIATION OF ELEMENTS.

We have seen in a former paper* that the problem of three bodies is one of integration and that with the exception of certain special cases the exact integrals cannot be found. But in such a system as that of the Sun and planets where nearly all the mass is in one body and the others revolve around it in orbits of widely different dimensions, methods of approximation can be readily applied. Let us consider the Sun and two planets. The first would move around the Sun in a conic section if it were not for the action of the second one. Let us imagine that the disturbing action is of the nature of blows on the moving body occurring at given intervals. Then as we have seen in part I the planet will always be moving in a conic section, but one whose elements change in a definite manner every time one of these blows is struck. If we take these small blows indefinitely near each other we have continuously varying elements. The real curve will not be a conic but we suppose that the body is always moving in one which changes so that it coincides with the real orbit at every point when the planet is at that place. The problem is to compute how these elements must vary.

If we let m_1 and m_2 represent the masses of the two planets and

* The problem of Three Bodies. POPULAR ASTRONOMY, December 1897.

M the mass of the Sun; x_1, y_1, z_1, r_1 the coördinates of m_1, and x_2, y_2 z_2, r_2 the coördinates of m_2 with respect to the center of the Sun as origin; ρ the distance between m_1 and m_2, then we shall have equations of the following type to be integrated

$$\frac{d^2x}{dt^2} + \frac{(M + m_1)}{r_1^3} x_1 = m_2 \left(\frac{x_2 - x_1}{\rho^3} - \frac{x_2}{r_2^3} \right) \tag{1}$$

If we neglect the right side which arises from the action of m_2 alone the system can be integrated. Then later we must vary the constants of integration, that is, the elements, so that the system is satisfied when the right member is included. Since we know that the orbits of the two planets after they are disturbed are almost exact ellipses we can find at what time x_1, x_2, ρ and r_2 take all possible values, hence we may consider the right side to depend only upon the time and the constant elements, and write (1)

$$\frac{d^2x_1}{dt^2} + \frac{(M + m_1)}{r_1^3} x_1 = \varphi(t) \tag{2}$$

This system will have a slight error in $\varphi(t)$ because we do not know *exactly* what functions of the time the quantities in the right member of (1) are. If we did that would constitute the solution of the problem. The system (2) is complex from the number of equations which must be solved at the same time. Since the one written involves y_1 and z_1 in r_1 it evidently cannot be treated alone, but must be included with all the others involving the same quantities. In place of discussing (2) we shall illustrate the principles involved by the single equation in x and t,

$$\frac{d^2x_1}{dt^2} + k^2x = f(t) \tag{3}$$

First let us neglect the perturbing part $f(t)$ and we shall have

$$\frac{d^2x}{dt^2} + k^2x = 0 \tag{4}$$

Multiplying through by dx and integrating we have

$$\frac{1}{2}\left(\frac{dx}{dt}\right)^2 + \frac{k^2x^2}{2} = \frac{c_1^2}{2} \tag{5}$$

Solving (5) for dt we have

$$dt = \frac{dx}{\sqrt{c_1^2 - k^2x^2}} \tag{6}$$

The well-known integral of this is

$$t = \frac{1}{k} \sin^{-1} \frac{kx}{c_1} + c_2 \tag{7}$$

$$\therefore \quad x = \frac{c_1}{k} \sin\ (t - kc) \tag{8}$$

Expanding we have

$$x = a_1 \sin\ (kt) + a_2 \cos\ (kt) \tag{9}$$

where $a_1 = \frac{c_1}{k} \cos\ (c_2 k)$ and $a_2 = -\frac{c_1}{k} \sin\ (c_2 k)$.

(9)is the solution of (4) where a_1 and a_2 are arbitrary constants. We may select them as such functions of t that (3) will be satisfied. Since we have two quantities, a_1 and a_2, at our disposal we are at liberty to impose one other condition upon them.

Let us substitute (9) in (3) and make it satisfy the equation. We must first compute $\frac{d^2x}{dt^2}$ from (9) regarding a_1 and a_2 as variables in t. We find

$$\begin{aligned} \frac{dx}{dt} &= a_1 k \cos\ (kt) - a_2 k \sin\ (kt) \\ &\quad + \left[\sin\ (kt)\ \frac{da_1}{dt} + \cos\ (kt)\ \frac{da_2}{dt}\right] \end{aligned} \tag{10}$$

We shall now impose for our arbitrary condition that

$$\sin\ (kt)\ \frac{da_1}{dt} + \cos\ (kt)\ \frac{da_2}{dt} = 0.$$

Differentiating (10) and omitting [ ] we have

$$\begin{aligned} \frac{d^2x}{dt^2} &= -a_1 k^2 \sin\ (kt) - a_2 k^2 \cos\ (kt) \\ &\quad + k \cos\ (kt)\ \frac{da_1}{dt} - k \sin\ (kt)\ \frac{da_2}{dt} \end{aligned} \tag{11}$$

Substituting k^2x and $\frac{d^2x}{dt^2}$ from (9) and (11) in (3) we find that our other condition is

$$k \cos\ (kt)\ \frac{da_1}{dt} - k \sin\ (kt)\ \frac{da_2}{dt} = f\ (t) \tag{12}$$

From the two conditions on a_1 and a_2

$$\left\{ \begin{aligned} k \cos\ (kt)\ \frac{da_1}{dt} + k \cos\ (kt)\ \frac{da_2}{dt} &= 0 \\ k \cos\ (kt)\ \frac{da_1}{dt} - k \sin\ (kt)\ \frac{da_2}{dt} &= f\ (t) \end{aligned} \right. \tag{13}$$

we find by ordinary elimination,

$$(14)\quad \begin{cases} k\,\dfrac{da_1}{dt} = -f(t)\cos(kt) \\ k\,\dfrac{da_2}{dt} = -f(t)\sin(kt) \end{cases}$$

Indicating the integration we have

$$(15)\quad \begin{cases} a_1 = \dfrac{1}{k}\int f(t)\cos(kt)\,dt + b_1 \\ a_2 = -\dfrac{1}{k}\int f(t)\sin(kt)\,dt + b_2 \end{cases}$$

where b_1 and b_2 are constants of integration. When $f(t)$ is given explicitly the integration can be performed, and these new values of a_1 and a_2 substituted in (9) will give the complete solution of (3). It can be very readily verified for a special case, as $f(t) = \cos(kt)$.

In the case of system (2) which is the problem under discussion we would arrive after considerable work at a system of equations quite similar to (15), where the a_1 a_2 etc. would be the variable elements, and the b_1 b_2 etc. the original elements.

They would have the forms,

$$(16)\quad \begin{cases} \delta a = a - a_0 = \int \psi_1(t)\,dt \\ \delta e = e - e_0 = \int \psi_2(t)\,dt \\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot \\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot \end{cases}$$

The $\psi(t)$ quantities depend upon $\varphi(t)$ in (2) and are infinite series. The nature of the variations of the elements evidently depends directly upon the nature of the terms of these series. In carrying out the integration terms are sometimes found of the form ct where c is a constant. They are called *secular terms*, for, as t approaches infinity the elements will increase or decrease without limit. If such terms occurred in the expression for the variations of a in (16) we might expect that the planets would recede from the Sun indefinitely, or be precipitated upon his surface. It was proved however by Laplace and Lagrange toward the close of the last century that such terms do not occur in the expressions for the variation of a. Poisson has since proved that they do not appear in the perturbations of the second order of a. They do however appear in the expressions for the variations of such elements as Ω and ω, but these perturbations do not threaten the stability of the system.

There are terms of the character $c_1 \cos(c_2 t)$ which occur in the expressions for the variation of every element. They are periodic,

increasing the elements for a time, then decreasing them, and the different terms often mutually destroying each other. Such variations do not in the long run change the condition of the system.

Some terms which have the form of those just considered become important, because the coefficients are very large. In these $c_1 = \frac{c_3}{i\,n + i^1\,n'}$ where i and i^1 are integers which go independently from minus infinity to plus infinity, and where n and n' are the mean motions of the disturbed and disturbing planet respectively.

If the periods are nearly commensurable n and n' are nearly commensurable. Then for certain values of i and i^1 the denominator will become very small and c_1 very large. These give rise to what are called the *long period inequalities*.

The geometrical meaning is that if the periods of the two planets are nearly commensurable the points of nearest approach of the planets will occur for a long time at about the same parts of their orbits, and the revolution of this point of nearest approach constitutes the *long period*. In the case of the mutual perturbations of Jupiter and Saturn these terms are very large and give rise to a great deal of trouble.

It is hoped that these necessarily imperfect and incomplete explanations will be of use to some, and will encourage them to go on to profounder studies in these attractive subjects. The difficulties in the way of getting a fair grasp of the methods employed are not insurmountable to the average student, while the benefits and pleasure derived are certainly beyond those obtained from computing cometary orbits. Teachers should be careful that they do not make the computing of orbits unduly prominent in their instruction in theoretical astronomy.

March 1898,

THE UNIVERSITY OF CHICAGO.

DETERMINATION OF PHYSICAL CONSTANTS BY THE U. S. COAST AND GEODETIC SURVEY.

E. D. PRESTON.

FOR POPULAR ASTRONOMY.

It is very desirable in scientific work to extract from the observations all the information that they are capable of yielding. The derivation of empirical formulæ embodying a fixed law of Nature may, besides establishing the truths which were the orig-

inal objects of the investigation, accidentally bring out an unsuspected fact. Some years ago it was discovered that terrestrial latitudes were subject to a change, and that the law of these changes could be formulated in a simple linear equation containing two unknown quantities. When the equations of condition were formed, which theoretically should entirely satisfy the observations, and when a solution was effected giving results which were supposed to leave outstanding only accidental errors, there appeared to be systematic discrepancies. Moreover, the difference showed a well defined uniform change increasing at one season of the year and decreasing at another. This phenomenon was none other than the effect of the aberration of light. It is well known that the velocity of light is about 10,000 times as great as that of the Earth, so that while the Earth travels one mile in its orbit the ray of light by means of which we take cognizance of any celestial object and make our measurements has traveled 10,000 miles. This amounts to saying that our telescope must be inclined at a slight angle in order to receive the ray of light, the angle depending of course on the direction of the Earth's motion with reference to the observed ray, and the so-called "constant of aberration" is nothing more than the maximum displacement of the apparent position of the star. This, of course, obtains when the motion of the Earth is at right angles to that of the ray of light. With these facts before us it is quite evident that the observations for the variation of latitude contained not only data sufficient to show how the latitude was changing but also the effect of the aberration besides. They could therefore be utilized to determine this last quantity and after that to find the size of the Earth's orbit. This has been done in the case of the observations made at Honolulu and San Francisco and the results of the work have just been published in Appendix 10, Report for 1896. In this report it is shown how nearly 7,000 equations are used to find the quantity sought. It is extremely gratifying to note that although the original observations were made to study only changes of latitude, they embodied sufficient material to determine with precision one of the fundamental constants of astronomy.

The final values obtained were:

Constant of aberration	20″.458
Solar parallax	8″.808
Sun's distance	92,820,000

NEWSPAPER ASTRONOMY.

R. M. McCREARY.

FOR POPULAR ASTRONOMY.

It is significant of an increasing interest in astronomy among the people that so many newspapers find space for items relating to astronomical events and for articles on astronomical subjects. It is not in the professedly scientific, semi-scientific and educational journals only that such articles and items appear; they abound in the columns of the leading religious, political and literary papers and in the magazines. Hardly one of the last runs through a volume that does not contain one or more articles on astronomical subjects; hardly an issue of any great weekly is barren in this regard; every daily paper is anxious for the news concerning current astronomical events, eclipses, discoveries of comets, erection of Observatories, etc. while many make the publication of astronomical articles a regular and prominent feature.

This is well. It is well because it indicates that there is among the people a growing taste for astronomy and an increasing desire for astronomical knowledge; it is well because it proves that many publishers know and are willing to supply the wants of their readers in this line; it is well because the outcome will be increased popular knowledge concerning the noblest of sciences, concerning astronomy, the science which more than all others, enlarges man's conceptions of the glory and grandeur of the universe, of the wisdom and power of its Creator and tends most to lead his mind "from Nature up to Nature's God."

Thus far it is well. But there are drawbacks. Many people have an irresistible, or at least an unresisted propensity for writing; they want to write something about something and they sometimes indulge their inclination by writing most about that of which they know the least. May not some of those who write astronomical articles for the newspapers belong to this class? Further; few editors know much, few, indeed, profess to know anything, about astronomy and consequently most of them are unable to exercise proper discrimination as to what, bearing on the subject, they ought or ought not, to publish. They take what comes along and let it go at that. It results that some of the "astronomy" that is disseminated among the people by the newspapers is hardly up to the standard that would be required in a text book.

Instances wherein incompetent writers have been permitted by

indiscriminating editors to "rush into print" are numerous. One instance only need be cited to prove what has been said. In a recent Sunday issue of a leading paper an article entitled, "The Earth Is Changing," appears. The writer of the article asserts and undertakes to prove, possibly does prove, by arguments derived from well known astronomical facts that some 10,000 years hence what he calls a "midwinter of the ages" with all its attendant inconveniences will settle down upon the northern hemisphere. The composition of the article proves its author's ability to write well—about a subject that he understands; its matter proves that he has read and studied somewhat about astronomy, but it proves likewise that, notwithstanding reading and study, his ideas about the subject are a little hazy. His philosophy may be all right but his astronomy is abominable. Hear him! He speaks about the "absolute pole of the heavens" as though the heavens had a pole, "absolute" or otherwise. What he means is plain enough to an astronomer but he did not write for astronomers. After a little he says that the motion in space of the Earth's axis whereby the terrestrial pole is made to describe a circle in the heavens is called the "procession of the equinoxes" and assigns as the cause of the phenomenon the attraction of the planets and the fact that the Earth is not a perfect sphere. Then he says, "further detail is unnecessary." That, at least, is true. And it is true, too, that further reference to the article for the purpose of proving that everything that is labeled astronomy and published in the newspapers does not tend to increase the sum of astronomical knowledge among the people is also unnecessary.

Yet, the article cited is an exception; most that appears in the magazines and newspapers on astronomy would bring no discredit upon a professedly astronomical publication. So that, after all, and notwithstanding the drawbacks, it is well that so much on the subject is printed in the newspapers. They are the channels through which astronomical instruction can be conveyed to the greatest number of people.

GREENSBURG, Pa.

THE MANUFACTURE OF GLASS FOR OPTICAL USES.

J. A. BRASHEAR.

It is difficult indeed to trace the history of optical glass in its earlier development. I have studied almost every available authority on the subject, and have concluded that no great weight

can be placed upon many of the earlier stories told us. Mollineux, in his *Dioptrica Nova*, written in 1690, says, "that the ancients had no knowledge of optical glasses is most evident from their universal silence in this matter; their most learned and inquisitive philosophers making no mention or at least hint thereof in their writings. And doubtless a contrivance of that universal use, beneficial to all old men, both in reading and writing, could not have been so concealed as that the least footsteps thereof should remain to posterity. The only relief they had for their decayed sights were certain colyria, or eye salves, and when they failed them they were left alone in the dark for minute and close objects." Pauciollus, in his *Rebus Inventio*, quotes this passage from Plautus *Ced › Vitrium*, "necesse est conspicillis uti," (literally something to see with), which, he says, cannot possibly mean anything else but the glasses in all spectacles; but Mollineux plainly states that such a passage is not to be found in Plautus.

In an Italian work published but five years before the remarkable work I have referred to (Mollineux), there is a statement that spectacles were invented about the year 1150, but this date is probably too early. It is, however, quite certain that the date of the discovery of lenses, as applied to spectacles, is somewhere between 1280 and 1311.

In a manuscript preserved in an Italian library, written in 1290, there is a sentence which, translated into English, reads thus: "I find myself so pressed by age that I can neither read nor write without those glasses they call spectacles, lately invented; to the great advantage of poor old men when their sight grows weak."

Friar Jordan, in a book of sermons printed in 1305, tells his audience that "it is not twenty years since the art of making spectacles was found out, and is indeed one of the best and most necessary inventions in the world."

From this and much other data it is quite certain that spectacles were known in the latter part of the thirteenth century.

Mollineux says that "there is no positive knowledge of who was the happy man that first hit upon this lucky thought. 'Tis true, indeed, if we credit the forementioned chronicle of the convent at Pisa, Friar Spina makes as fair a challenge to the invention as the first author who refused to communicate it. But I am apt to believe that whoever this close man was that would not impart to Spina, he was a friar, and that these monkish men and Jordan among the rest, had this invention whispered among themselves before it was public, and that they all had the first hint from our countryman, Friar Roger Bacon."

After a great deal of research I have failed to find any satisfactory data as to the character of the glass used in making spectacle lenses. That it was crown glass there seems little doubt, for the reason that all flint glass made during this period was very impure; indeed, up to the beginning of the present century no flint glass had been produced that was of any value for optical purposes.

It is entirely foreign to the purpose of this paper to trace the history of glass-making, outside of its association with the development of optical instruments, interesting as this part of the subject may be; but when we consider that the manufacture of glass extends far back into the past, perhaps forty centuries, it is rather surprising that we have so little information as to the kind of glass used in the manufacture of spectacle and other forms of lenses, such as those used in the earlier telescopes. It is quite certain that window glass was made in the thirteenth century, and mirror glass was made in Venice as early as 1317, but glass mirrors did not displace steel mirrors, as they were made up to the sixteenth century, when the art of silvering mirrors was perfected, although process of silvering had been known for four hundred years.

As the making of window and mirror glass was contemporaneous with the invention of spectacles, there remains little doubt in my mind that the crown glass, from which lenses were made, was selected from the window or mirror glass used at that time, and this same method of obtaining glass for spectacles and other lenses must have been followed for more than three centuries.

Through the courtesy of Admiral Mouchez, Director of the Paris Observatory, I was permitted, in 1892, to examine some of the largest objectives made by Divini, of Rome, and Campani, of Bologna, about the middle of the seventeenth century, one of which was 6 inches diameter. I am quite sure that the material out of which these lenses were constructed is made similar to the mirror glass manufactured at the time they were made. If my memory serves me right, the 7-inch lens was not over ¼ of an inch in thickness. I well remember examining the object glass used by Cassini, with which he discovered the double ring of Saturn. It was about 4½ inches in diameter, and not over $\frac{3}{16}$ thick at the edge, and as the radius of curvature was, I should say, not less than 40 feet, the lens was very little thicker in the centre than at the edge. Owing to the many little scratches on the surface of this historic glass, I was not able to determine the character of the material in it, but it must have been of fairly

good quality, or Cassini could not have made such discoveries with it.

A new era in telescope-making dawned upon the world when Dollond made his wonderful discovery of correcting the chromatic aberration of the object glass, mention of which has been made in the address of our President.

But Dollond's discovery required the use of both crown and flint glass. Crown glass of fairly good size could be procured by a careful selection of the best grades of plate glass, but flint glass of sufficient purity could not be obtained for objectives of more than three to three and a half inches diameter, and then only by chance could pieces be found by searching through a large mass of material at the glass works. So serious did the problem become that the Academy of Sciences at Paris offered a prize to the successful maker of flint glass for optical purposes. Macquer, a celebrated chemist; Roux of the great St. Gobian glass works; Albert of the Langress glass factory, all tried to solve the problem, but failed completely, and it is stated by Bontemps, one of the best authorities on the manufacture of glass, that out of a hundred pounds of the best flint glass any of the makers could produce, they were often unable to get the material for an objective of 3 inches diameter, and at this period—about 1811—a piece of good flint glass 3¾ inches diameter, free from imperfections, was considered of great value.

In an old and very rare book by Dr. Kitchiner, I find the following note: "I am informed by the Messrs. Dollonds that between the years 1760 and 1765 they met with a pot of uncommonly fine flint glass: Crown glass was also then to be had of much superior quality than they had been able to procure since the cessation of the glass house of Ratcliffe—however, they found that they could not even then with these confessedly superior materials produce an object glass of larger aperture than 3¾ inches. Such was the case then when it was much more plentiful than it is now." This note written in 1818 shows that it was a mere chance melting of glass that gave the Dollonds their opportunity to make lenses of so large an aperture as 3¾ inches.

When Peter Dollond made a triple lens object glass of 3¾ inches aperture for Dr. Kitchiner, so great was his interest in it that he remarked to Kitchiner, "yes, that object glass is one of the things that is to make me immortal."

Bontemps is authority for the statement that M. D'Artigues, one of the best makers of crystal glass in France, gave his undivided attention to the production of optical flint glass, but

after many trials succeeded only in producing, probably by mere chance, a few pieces, one of which was good enough to make a lens of 4 inches diameter. An objective was made from this large (?) piece of glass by M. Cauchoix and presented to the class of physical and mathematical sciences at the Institute of France by M. D'Artigues.

M. Biot made a report of M. D'Artigues' method, which, while it gave in detail the various steps of the process, proved very unsatisfactory, for summing it up, Bontemps puts it thus: "Make a pot of good flint glass with all possible care by M. D'Artigues' method and you will find in it *some glass* for optical purposes."

In Biot's report he made mention of the fact that "there was still fine striæ left in the glass made by Mr. D'Artigues,—that there was not enough to do any harm,—but which he would ask him to remove if possible in order to obtain the best objectives."

But the time had come that, with the want, came a man to supply it; and, like many of the most valuable inventions that have opened new eras in the world's history, this one came from where it was little expected. Piere Guinand, a watchmaker of Brenets, near Neuchatel, in Switzerland, had learned of the difficulty of making flint glass, and, although he had no knowledge of the processes employed, ignorant in a great measure of the laws of physics and chemistry, he attacked the problem in a variety of ways, each time gaining knowledge that was invaluable to him. He seemed to be endowed with the spirit of research, coupled with great perseverance and patience, and although he worked years without results, success finally came to him.

There are two serious difficulties in making flint glass; one is that of a tendency of the oxide of lead—which is one of the important constituents of this glass—to fall to the bottom of the pot or to crucible when it is in a state of fusion. This tendency of the lead oxide to sink produces unequal density in the various horizontal layers of the glass, which in itself would not be so important if it were possible to cut truly horizontal sections from the coolest mass; but this is, in the very nature of the case, an impossibility, for in cooling the glass breaks up into more or less irregular shapes, and from these pieces must be selected the material for lenses.

Another and most serious difficulty is to get rid of striæ or chords in the glass, which requires a very perfect mixture of the fluid mass, but which is rarely ever attained.

Guinand's process is essentially as follows: A single pot or crucible, made of very pure clay, with an opening in the side near

the top, is placed in a furnace especially arranged so that the heat can be applied all around it and as equally as possible. The material for the glass is placed in the pot or crucible in two or three charges, separated by an interval sufficient to allow the previous charge to settle. The material, or batch, as it is technically called, is now thoroughly melted, requiring about thirty hours for perfect fusion, a very high temperature being required. Tests are taken from the melted material from time to time until the test pieces show not only perfect fusion, but the greatest possible freedom from air bubbles. At this stage of the process Guinand's invention is brought into requisition; namely, a thorough stirring of the fluid mass. For this purpose a stirrer, made of the purest clay, is introduced into the pot, having been previously brought to quite a high temperature so as not to chill the glass. This stirrer, called a "Guinand," is so made that an iron handle can be secured inside of the upper end of it, the long handle of the iron part being carried in a shieve on the side of the furnace so as to carry its weight.

The process of stirring is now commenced, and is a most laborious task, not only on account of the character of the work, but of the excessive temperature that must be endured by the workmen.

Two men are required to do this work, as it must be kept up for about three hours, or until the mass has become so stiff that the stirrer can no longer be moved by the operators. M. Feil told the writer some years ago that this process of stirring is most exhausting in its nature, and that few men can stand it. The temperature is allowed to fall during this and subsequent stirrings, so that the metal may approach so nearly to the solid state that the metallic oxides will not sink. For the commoner grades of optical flint glass one stirring is usually considered sufficient, but for the best grades the temperature is raised after the first stirring, and a second and sometimes a third stirring is found necessary to work all the remaining air bubbles to the top, as well as to so thoroughly mix up the mass that it will be of as nearly as possible the same density from top to bottom. So difficult is it to move the stirrer toward the end of the process that the "Guinand," or clay stirrer, cannot be moved around the pot in less than six to seven seconds. No doubt mechanical methods could be devised for this part of the work. The iron handles of the stirrer must be frequently changed on account of becoming so hot as to form scales of gray oxide, which, if they should fall into the glass, would ruin it for optical purposes. One of the greatest

difficulties the optical glass maker has to contend with is the presence of iron in the clay from which the pots or crucibles are made.

After the final stirring has been completed, double covers are placed over the mouth of the pot and carefully luted with clay. Every avenue for the ingress or egress of air in the furnace is carefully sealed, and the furnace, pot, and glass allowed to cool during a period of six to ten days, according to the weight of the melted mass and size of the furnace.

The front of the furnace is now taken down and the crucible drawn out in order to get at its contents. The pot is usually found pretty well shattered, and is broken away from the now solidified and cooled mass within it. The glass is also found broken into irregular lumps of greater or less size, but all are carefully examined and set aside for use according to their value.

[To be Continued.]

OCCULTATION OF 26 ARIETIS OBSERVED PHOTOGRAPHICALLY.

EDWARD C. PICKERING.

The disappearance of a bright star when occulted by the Moon is always a striking phenomenon. There is no celestial event whose time is susceptible of more precise determination. For many years various plans have been suggested, both here and elsewhere, by which this time could be determined with greater accuracy than by ordinary visual observation. In fact, the apparatus for photographing the eclipses of Jupiter's satellites, used here for several years, was devised in part for this purpose.

On February 25, 1898, Mr. Edward S. King for the first time succeeded in satisfactorily photographing the occultation of a star. The apparatus used was an improved form of that constructed for photographing the eclipses of Jupiter's satellites, and described in the *Astrophysical Journal*, Vol. I, p. 146. The plate was moved automatically every second by means of an electromagnet. A motion of about 0.03 cm. was given to the plate whenever the circuit was closed, and of an equal amount when it was opened. Connecting the apparatus with the standard clock, Frodsham 1327, two images alternately faint and bright were obtained every second. As the faint images are three magnitudes fainter than the bright images, the ratio of the durations was about one to sixteen, so that the absolute durations were

$0^s.06$ and $0^s.94$. It is here assumed that, as the times of exposure were very short, the chemical action was proportional to the time. This assumption is verified by actual measurement.

Considering only the images taken during the minute following $6^h\ 35^m\ 0^s$, the bright images of 26 Arietis, as shown below,* are equally intense including that having an exposure lasting from $50^s.06$ to $51^s.00$. Since this image appears to be as bright as the others, the light of the star could not have begun to diminish much before the time $51^s.00$. If the star had disappeared suddenly at $50^s.9$ the last image would be at least 0.12 of a magnitude fainter than the others, an amount readily measurable. The next image is apparently invisible. Had the disappearance taken place at $51^s.06$ the image would appear, and would be as bright as the other faint images. A slight darkening of the film is perceptible near the position the next image would have had, with an intensity nearly equal to that of the fainter images. If this were due to the star, it would denote that the latter suddenly disappeared at about $51^s.12$. The absence of the preceding image would indicate a more gradual disappearance. In any case, the time is fixed at $51^s.1$, to within one tenth of a second. As the clock was $2^m\ 19^s.4$ fast, not including armature time, the corresponding Greenwich Mean Time is $12^h\ 54^m\ 26^s.5$. By using shorter exposures the uncertainty in the time of disappearance can doubtless be greatly reduced; especially in the case of the brighter stars. Since satisfactory images of 26 Arietis, magnitude 6.1, were obtained in $0^s.06$, it is probable that occultations of stars as faint as the ninth magnitude can be observed photographically.

Measures were next made of the intensity of the last five images of 26 Arietis, to see if there was any diminution in light due to the absorption of a lunar atmosphere. The distances of these images from the Moon's limb were $1''.8$, $1''.4$, $1''.0$, $0''.6$, and $0''.2$, respectively. The corresponding changes in light, expressed in magnitudes as compared with ten more distant images, were $+\ 0.3$, $+\ 0.03$, $-\ 0.02$, $+\ 0\ 03$ and $-\ 0.02$. A positive sign denotes that an image was fainter than those at a greater distance from the Moon. From this it appears that no diminution in light was perceptible. No correction need be applied to any of the above calculations for the diameter of the star's disc, since, assuming its intrinsic brightness equal to that of the Sun, its time of disappearance would be only $0^s.002$ (Proc. Amer. Acad. XVI, p. 1).

In this connection it is interesting to note that the determination photographically of the position of the Moon, by means of

* Reproduction of photograph failed.

a star about to be occulted, was one of the subjects investigated by Professor G. P. Bond forty years ago. He obtained a number of photographs of the Moon and α Virginis shortly before the occultation of the latter on June 2, 1857.

March 3, 1898,

HARVARD COLLEGE OBSERVATORY,
Circular No. 26.

PLANET NOTES FOR APRIL.

H. C. WILSON.

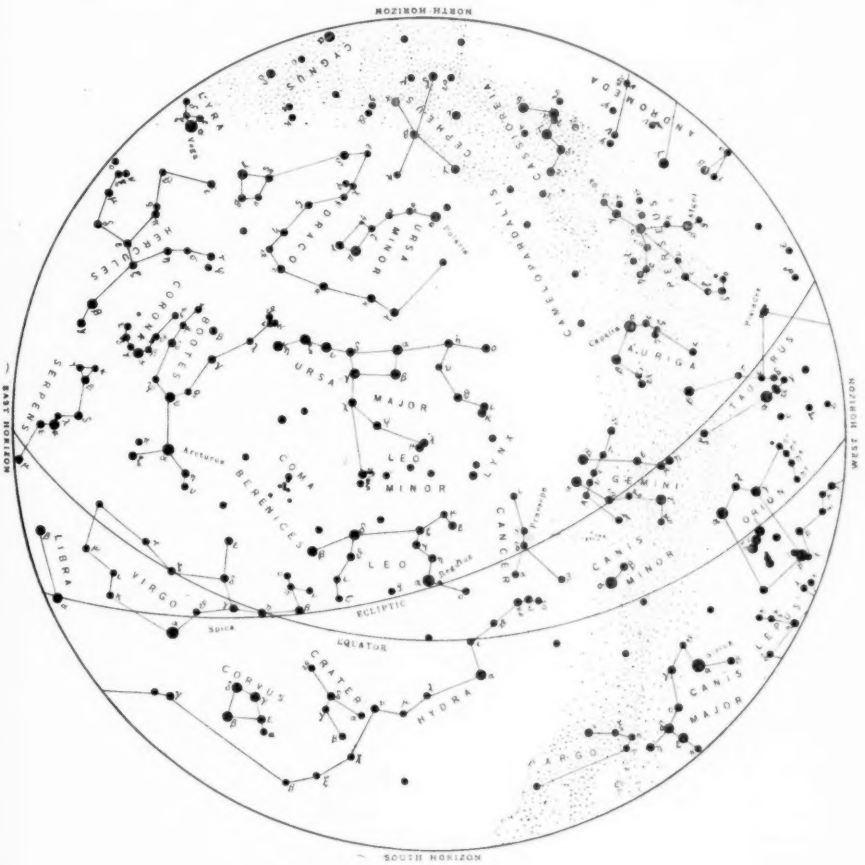
Mercury and *Venus* are both evening planets just now, and may be seen toward the west soon after sunset, but are visible for only a short time. They are in a part of the sky where there are no first magnitude stars, so that one need not fear mistaking a star for either planet. Venus is the brighter of the two planets and is nearer the horizon than Mercury. The distance between them will increase until April 8, when mercury will be about 7° northeast, on a line almost perpendicular to the horizon, from Venus. On April 10 Mercury reaches greatest elongation east from the Sun, 19° 34′ and turns westward. The Earth's movement, however, apparently carries him eastward until the 20th, when Mercury becomes stationary in right ascension for a short time, then begins retrograde motion among the stars, describing the great bend in his apparent path, shown upon our diagram in the January number of POPULAR ASTRONOMY, p. 493. In the mean time the two planets approach each other until they are in conjunction in right ascension, but over 3° apart in declination, on the 18th. They then recede from each other until Mercury is lost in the rays of the Sun, on his way to inferior conjunction with the latter, which will occur on the last day of the month.

Mars is a morning planet, seen toward the southeast before sunrise but not yet in good position for observation.

Jupiter is in good position for observation during the latter part of the evening. None can mistake this glorious planet, seen toward the east as soon as twilight darkens, rising higher and increasing in splendor until it reaches the meridian between eleven and twelve o'clock. Even the first magnitude star Spica, which is Jupiter's neighbor in the constellation Virgo, pales into insignificance in the presence of the splendid glow of the giant planet. With a good telescope the the beauty of this planet with its colored belts, ever-changing in detail, and its retinue of glittering satellites ever-shifting in configuration, is something not to be described. It is something not to be grasped at a casual view, but requires repeated effort and long continued, careful and patient scrutiny under the best conditions. That observer who can give hour after hour and night after night to the study of this planet, making careful records and drawings, will not only be likely to gather many data which will be of scientific value, but will be amply repaid by the exquisite views of the detail of the planet, which come only at rare intervals and to the trained eye. We give this month the times of those phenomena of the satellites of Jupiter which will be visible in the United States, and hope that many may be able to witness some of these phenomena. The daily diagram

on another page will enable the observer to identify the satellites, which look so much alike that, without some such aid, it is impossible to tell them apart.

Saturn is to be seen toward the south in the morning. Our students have in the last few days obtained some very good views of this planet in spite of its low altitude. Saturn has begun to retrograde slowly, but the movement during this month will scarcely be noticed.



THE CONSTELLATIONS AT 9 P. M., APRIL 1, 1898.

Uranus is west of Saturn near the star β Scorpionis.

Neptune may be found with a telescope in the early evening. It is in Taurus about 4° west from the star Zeta.

The Sun. Two new groups with many spots appeared by rotation March 5. One of these groups developed finely while in transit, containing as many as 30 umbræ. On March 23 all spots had disappeared.

The Moon.

		Phases.	Rises. (Central Standard time at Northfield; Local Time 13m less)		Sets.	
			h	m	h	m
Apr.	6	Full Moon	7	6 P. M.	5	36 A. M.
	13	Last Quarter	1	50 A. M.	11	3 "
	20	New Moon	4	44 "	7	20 P. M.
	28	First Quarter	10	55 P. M.	1	42 A. M.

Occultations Visible at Washington.

Date 1898.	Star's Name.	Magnitude.	IMMERSION. Washington M. T. h	m	Angle from N pt. °	EMERSION. Washington M. T. h	m	Angle from N pt. °	Duration. h	m
Apr. 2	10 Sextantis	6.0	10	45	131	12	1	300	1	16
3	34 Sextantis	6.7	9	30	155	10	42	262	1	12
9	α Scorpii	1.2	17	11	135	18	5	227	0	54
11	λ Sagittarii†	2.9	11	44	62	12	38	300	0	54
13	o Capricorni†	6.2	13	34	18	14	7	315	0	33
22	9 Tauri	7.0	7	22	85	8	20	270	0	58
24	118 Tauri‡	5.7	10	32	76	11	19	299	0	47
26	44 Geminorum	6.0	6	51	161	7	44	242	0	53
27	85 Geminorum	6.0	6	32	129	7	55	287	1	23
28	54 Cancri	6.3	11	2	81	11	51	332	0	49
29	ξ Leonis	5.3	7	7	185	7	51	246	0	44

Phenomena of Jupiter's Satellites.

Central Standard Time.

		h	m				h	m		
April	1	6	36 P. M.	I	Oc. Dis.	April		9	35 P. M.	I	Tr. Eg.
		8	26 "	II	Oc. Dis.			10	6 "	I	Sh. Eg.
		8	59 "	I	Ec. Re.		17	7	15 "	I	Ec. Re.
		11	16 "	II	Ec. Re.			7	17 "	II	Tr. In.
	2	6	5 "	I	Tr. Eg.			8	22 "	II	Sh. In.
		6	17 "	I	Sh. Eg.			9	48 "	II	Tr. Eg.
	3	6	58 "	III	Oc. Dis.			10	55 "	II	Sh. Eg.
		10	24 "	III	Ec. Re.		18	1	33 A. M.	III	Oc. Dis.
	7	1	54 A. M.	I	Oc. Dis.		21	8	21 P. M.	III	Sh. Eg.
		3	56 "	II	Tr. In.		22	2	40 A. M.	I	Tr. In.
		11	9 P. M.	I	Tr. In.			11	49 P. M.	I	Oc. Dis.
		11	28 "	I	Sh. In.		23	2	41 A. M.	I	Ec. Re.
	8	1	24 A. M.	I	Tr. Eg.			9	6 P. M.	I	Tr. In.
		1	43 "	I	Sh. Eg.			9	46 "	I	Sh. In.
		8	20 P. M.	I	Oc. Dis.			11	21 "	I	Tr. Eg.
		10	42 "	II	Oc. Dis.		24	12	1 A. M.	I	Sh. Eg.
		10	52 "	I	Ec. Re.			9	9 P. M.	I	Ec. Re.
	9	1	53 A. M.	II	Ec. Re.			9	33 "	II	Tr. In.
		7	50 P. M.	I	Tr. Eg.			10	56 "	II	Sh. In.
		8	12 "	I	Sh. Eg.		25	12	5 A. M.	II	Tr. Eg.
	10	7	33 "	II	Tr. Eg.			1	29 "	II	Sh. Eg.
		8	21 "	II	Sh. Eg.			6	30 P. M.	I	Sh. Eg.
		10	14 "	III	Oc. Dis.		26	8	24 "	II	Ec. Re.
	11	2	22 A. M.	III	Ec. Re.		28	6	34 "	III	Tr. In.
	15	12	54 "	I	Tr. In.			9	15 "	III	Tr. Eg.
		1	22 "	I	Sh. In.			9	36 "	III	Sh. In.
		3	9 "	I	Tr. Eg.		29	12	19 A. M.	III	Sh. Eg.
		3	38 "	I	Sh. Eg.		30	1	35 "	I	Oc. Dis.
		10	4 P. M.	I	Oc. Dis.			10	53 P. M.	I	Tr. In.
	16	12	46 A. M.	I	Ec. Re.			11	41 "	I	Sh. In.
		12	58 "	II	Oc. Dis.	May	1	1	8 A. M.	I	Tr. Eg.
		7	21 P. M.	I	Tr. In.			1	56 "	I	Sh. Eg.
		7	51 "	I	Sh. In.						

Ec. Dis. = Eclipse disappearance; Ec. Re. = Eclipse reappearance; Oc. Dis. = Occultation disappearance; Oc. Re. = Occultation reappearance; Sh. In. = Ingress of shadow upon disc of planet; Sh. Eg. = Egress of shadow from disc; Tr. In. = Ingress of satellite in transit across disc of planet; Tr. Eg = Egress of satellite.

Jupiter's Satellites for April.

Central Standard Time.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I.

III.

II.

IV. No Eclipse

Configuration at 10h 30m for an Inverting Telescope.

Day.	West.	East.
1	·4 3·	○ ·1 ·2●
2	·3 ·4 ·1	○ 2·
3	2·	○ ·4 ·3 ·1
4	·2 ·1	○ ·4 ·3
5		○ 1· 2· 3· ·4
6	·1	○ 2· 3· ·4
7	2· 3·	○ 1· ·4
8	3·	○ ·1 4· ·2●
9	·3 1·	○ 2· 4·
10	2·	○ ·1 4· ·3●
11	·2 1·	○ 4· ·3
12	4·	○ 1· ·2 3·
13	4· ·1	○ 2· 3·
14	4· 2· 3·	○ 1·
15	4· 3· ·2	○ ·1●
16	·4 ·3 1·	○ ·2
17	·4 ·3 ·2	○ ·1
18	·4 ·2 1·	○ ·3
19	·4	○ ·2 ·1 3·
20	·1	○ ·4 ·2 3·
21	2· 3·	○ 1· ·4
22	3· ·2 ·1	○ ·4
23	○ 1· ·3	○ ·2 ·4
24	○ 2· ·3	○ ·1 4·
25	·2 1·	○ ·3 4·
26		○ ·2 ·1 ·3 ·4
27	·1	○ ·4 ·2 3·
28	2· ·4 ·3	○ 1·
29	·3 ·4 ·2 ·1	○
30	4· ·3	○ 1· ·2

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

1898.

U CEPHEI.

	d	h
May	1	16
	6	15
	11	15
	16	15
	21	14
	26	14
	31	14

δ LIBRAE.

	d	h
May	3	9
	5	17
	10	9
	12	17
	17	8
	19	16
	24	8
	26	16

RS SAGITTARII.

	d	h
May	6	18
	11	14
	18	20
	23	16
	28	12
	30	22

U CORONÆ.

	d	h
May	7	15
	14	13
	21	11
	24	21
	28	8
	31	19

U OPHIUCHI.

	d	h
	Every 10th min.	
	P = 20h.1	
May	8	18
	17	3
	25	13

W DELPHINI.

	d	h
May	14	22
	19	17
	24	13

The above ephemeris is based on the elements of Chandler's Third Catalogue and supplements. The times (except for RS Sagittarii) are taken from Dr. Hartwig's ephemeris in the *Vierteljahrsschrift*.

Maxima and Minima of Long Period Variables.

1898 June.

MAXIMA.

		Mag.	Day
114	S Ceti	7.5	10
466	U Piscium	9.5	17
1222	R Persei	8.5	30
2528	R Geminorum	7	1
2691	T Canis minoris	9.5	23
2815	U Geminorum	9.3	23:
2857	U Puppis	8.5	7
3184	T Hydræ	7.5	27
3994	S Leonis	9.5	7
4377	T Virginis	8.5	30
4826	R Hydræ	4.5	14
4847	S Virginis	6.5	17
5501	S Serpentis	8	11
5887	V Ophiuchi	7	1
5931	S Ophiuchi	8.5	17
6512	T Herculis	7.5	7
7261	R Delphini	8.5	25
7944	T Pegasi	9	19

MINIMA.

		Mag.	Day
22	V Sculptoris	< 12	—
513	R Piscium	< 13	29
806	*o* Ceti (Mira)	9	16
906	R Trianguli	11.5	19

MINIMA, CONTINUED.

		Mag.	Day
1577	R Tauri	13	6:
1582	S Tauri	13	26?
1894	T Columbæ	11	—
2583	L_2 Puppis	6	23
2742	S Geminorum	< 13	30:
3825	R Ursæ Majoris	12.5	24
4225	X Centauri	12	23:
5070	Z Virginis	< 14	—
5095	R Centauri	9	23:
5194	V Bootis	9.5	1
5583	X Libræ	14	24
5593	W Libræ	< 14	—
5889	U Herculis	12	21
5955	R Draconis	12.5	22
6044	S Herculis	12	18:
6331	RU Scorpii	12.5	—
6624	T Serpentis	< 13	—
7192	Z Cygni	11.5	16:
7252	W Capricorni	< 14	11:
7571	V Capricorni	14	—
7609	T Cephei	9.5	6
7783	RU Cygni	9	—
7999	X Aquarii	13	—
8373	S Pegasi	13	9:

The data for long period variables are taken from Dr. Chandler's ephemeris in *Astronomical Journal* No. 420.

2815 *U GEMINORIUM.* Following are the particulars of the maximum noted in the last number. The initials are given of the observers. Messrs Daniel Sperra and Parkhurst. Thanks to the co-operation, the maximum was well covered, in spite of the unfavorable conditions.

1898 Gr. M. T.		M.				M.		
Feb. 2.50	<	12.5	P.	V not seen.	Feb. 7.56	9.6	D.	good.
3.54		11.8 ±	P.	doubtful.	10.62	9.2	S.	good.
4.69	<	9.6	D.	V not seen.	13.60	9.6	S.	fair.
5.54		9.70	P.	bright Moon near.	13.67	9.8	D.	good.
6.52		9.5	S.	Moon.	14.56	10.1	D.	
6.56		9.6	P.	Moon, clouds.	15.52	10.6	P.	clouds.
7.50		9.2	S.	poor.				

The curve would indicate that the maximum was of the "long" type, (See Mr. P. S. Yendell's article in POPULAR ASTRONOMY, May, 1897) the star remaining above normal light for 16 or 18 days. The sudden rise occurred some time between Feb. 3 and 5, and the maximum perhaps about Feb. 8, at 9.2 mag.

THE SYSTEM OF β LYRÆ. Professor G. W. Myers, Director of Observatory of the University of Illinois, at Champaign, read a very important paper with the above title, at the Yerkes Observatory Conference, in October, 1897. The paper was published in the *Astrophysical Journal* for January, 1898. The following are his conclusions.

"1. The photometric estimates of β Lyrae's variability may be explained easily within the limits of the errors of these estimates by the aid of the satellite theory.

2. The bodies may be regarded as similar ellipsoids of revolution.

3. The orbit of the secondary body is nearly circular and its plane passes almostly exactly through the Sun.

4. The common flattening of the ellipsoids differs but little from 0.17 and, aside from librations, the periods of rotation and revolution are equal.

5. The larger body is about 0.4 as bright as the smaller.

6. The distance of centers is extremely small, about 1/8 of the semi-major axis of the larger ellipsoid.

7. From Lindemann's chief epoch for 1892 the orbital eccentricity of the system must have increased from 1855. Beloposky's spectroscopic observations indicate the same.

8. The motion of the center of gravity of the system with respect to the Sun is very small.

9. The semi-major axis of the orbit of the companion is about 50,000,000 kilos.

10. The mass of the larger body is 21 times, and of the smaller 9.5 times the solar mass.

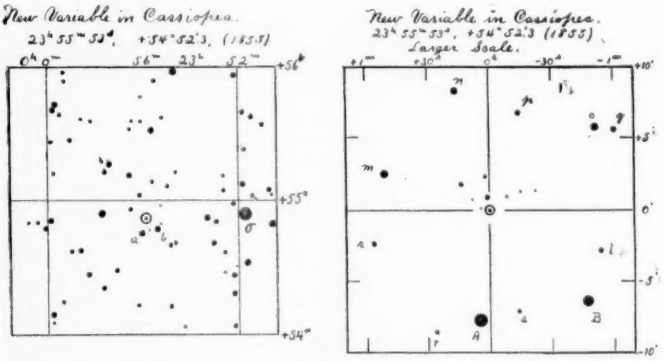
11. The densities of the companions are nearly the same.

12. The mean density of the system is comparable with atmospheric density, or the "system" (for such, I think, it must now be called) is in a nebulous condition.

13. In conclusion it may be said that the spectroscopic and photometric observations, which were available to me for the foregoing discussion, so far from being widely discordant, as some have thought, agree with each other remarkably closely."

The vew variable in Cassiopea, for which charts are here given, was mentioned on page 55 of the March number. It is of especial interest as it is easily found, 40′ of arc following the 5th magnitude star *sigma* Cassiopeae. The comparison star *A* is *DM.* + 54°, 3103, 7^m.0; *B* is + 54°, 3101, 8^m.4. The 8 stars near the variable are as follows, the magnitudes being only approximate for identification:

	Co-or. from V. R. A.	Decl.	m
k	− 3·0	+ 1.3	12
h	− 2.0	+ 1.2	11.6
g	− 1.2	+ 1.0	11.8
d	+ 0.3	+ 2.3	11.3
f	+ 0.6	+ 0.2	12
b	+ 0.1	+ 0.9	10.2
e	+ 1.2	+ 0.8	12
c	+ 1.9	+ 1.8	10.4



The star occupying the position of the variable as given in Harvard College Circular No. 24, was 9.5 magnitude March 4. The identification depends on the position, as measured with the micrometer, from the catalogue stars *A* and *B*.

Anderson's New Variable in Lynx.—This star was announced by Anderson in *Astronomische Nachrichten* No. 3467. He found it 10.5 magnitude 1897 Apr. 21, and 9.5 magnitude Dec. 17. According to my observations it declined from 10.0, 1898 Jan. 16 to 10.8, March 13. I have measured its place relative to the neighboring star, DM. + 58°, 960, which is No. 4675 in the Helsingfors-Gotha Astron. Gesell. Catalogue, with the result:

R. A. 6^h 32^m 2.7^s, Dec. + 58° 2′ 45″, (1855)
35 56.4 0 33 (1900)

J. A. PARKHURST.

Suggestions to Observers of Variable Stars.—The usual form of notation for recording observations of variable stars by the Argelander method is *a*2*v*, *v*3*b*. If one *v* be dropped, and the remaining parts written together, we have, *a*2*v*3*b*; a form well known to variable star observers. If the sign *plus* be

substituted for v, to designate the variable, we have $a2 + 3b$; a very neat and mathematical looking expression.

This method facilitates the formation of the light-scale, inasmuch as the sum of the intervals can be read at a glance, and with less liability to error than the usual method.

I would also suggest that a record of the minimum visible, or the faintest star seen, might be useful to indicate the degree to which the seeing is affected by moonlight, haze, etc. If the observer has a column in his record book especially for the purpose, this observation can be recorded by means of a single letter, and would certainly increase the value of the record. It would also be of value in cases where the variable is invisible; for the observation would set a superior limit to its brightness.

The presence of moonlight, haze, etc., or the condition of the seeing, can likewise be recorded in a column by means of a single letter. For this purpose the initial letter of the word used, would be the simplest and best; but, to avoid mistakes the column used for this purpose, as well as that for the "minimum visible," should be properly headed.

Clearness of record, next to carefulness in observing, cannot be too strongly urged, and should not be sacrificed for brevity. How often it could be wished that the ancient and mediaeval astronomers—and it is to be feared some modern ones too—had been more explicit in their records. Let us not have the same thing said about *our* records by future generations.

The foregoing suggestions may not all be new; but I trust that they will, at least, stimulate thought on the subject, and lead to more accurate, as well as more rapid methods of recording the phenomena of the variable stars.

Hawthorne, Penn'a. ZACCHEUS DANIEL.
1898 February 25.

COMET NOTES.

New Comet *b* 1898, (Perrine).—A new comet was discovered on the morning of March 20 by C. D. Perrine at Lick Observatory. It is described in the telegram announcing the discovery as 2′ in diameter, seventh magnitude, with a strong central condensation and a tail one degree long. We were able to observe it at Northfield on the morning of March 24 and to obtain a photograph March 25. In the 16-inch telescope the comet has a nucleus, almost stellar in appearance and of about the eighth magnitude, surrounded by strong condensation of nebulosity 3′ or 4′ in diameter, and a tail spreading to 5′ or 6′ diameter before leaving the field of view. The northern half of the tail is considerably brighter than the southern. In the 5-inch finder the tail could be traced for about a degree and a half.

Three photographs were taken at the same time on March 25 with an exposure of 40 minutes. That taken with the 8-inch telescope shows a dense coma 2′ in diameter, with the nucleus eccentrically situated within it, and a tail about 15′ long, spreading at an angle of about 25°. The photograph taken with the 2½ inch projecting lens shows two tails, the one straight, narrow and about 1°.7 long, directly opposite the Sun, the other curved toward the rear of the comets movement, spreading to several times the width of the head and a little less than a degree in length. These probably correspond to the hydrogen and hydrocarbon types of comet tails. The plate used in the six inch camera was defective but it confirms the details obtained by the smaller lens.

Two observations obtained at Lick Observatory have been telegraphed us by the courtesy of Mr. John Ritchie, Jr. These with the one obtained at Northfield are as follows:

Observer.	Greenwich M. T.	App. R. A. h m s	App. Decl. ° ′ ″
Perrine	March 20.0374	21 18 36.9	+16 43 23
Hussey	22.0532	21 25 59.8	+18 49 17
Wilson	23.9342	21 33 3.6	+20 46 20

From these data the writer has computed the following elements, which represent the observations to the nearest tenth of minute of arc:

$$T = 1898 \text{ March } 16.7128$$
$$\omega = 46^\circ\ 51'.7$$
$$\Omega = 262\ \ 14\ .9$$
$$i = 72\ \ 18\ .1$$
$$q = 1.0964$$

Before these computations were finished, elements and an ephemeris by Hussey and Perrine were telegraphed from Lick Observatory, and as the elements agreed closely with our own it did not seem necessary to proceed further.

ELEMENTS OF COMET *b* 1898.

By Hussey and Perrine, from observations March 20, 22 and 23.

$$T = 1898 \text{ March } 18.67$$
$$\omega = 49^\circ\ \ 2'$$
$$\Omega = 264\ \ 7$$
$$i = 72\ \ 48$$
$$q = 1.1003$$

Ephemeris of Comet *b* 1898.

Greenwich Midnight.	R. A. h m s	Decl. ° ′	Light
March 26	21 44 24	+23 23	0.99
30	22 0 28	+27 26	
April 3	22 17 32	+31 21	
7	22 35 32	+35 4	0.89

It will be seen from these calculations that the comet is already past perihelion, and is not likely to be any brighter than now. It is in the western part of the constellation Pegasus and is moving northeastward toward Cassiopeia.

Discovery of Comet *b*, 1898. (Perrine.) This comet was discovered by the writer about 4:30 A. M. of March 20. Its position at $0^h\ 53^m\ 56^s$ Greenwich mean time was *R. A.* $21^h\ 18^m\ 36^s.89$, declination $+16^\circ\ 43'\ 23.3''$. It was then near the western limits of the constellation *Pegasus*, a little north and west of the star *Iota*.

It is moving north one degree per day and west about the same amount. This motion is almost parallel with the horizon of northern mid-latitudes. In appearance the comet is typical of the rather large class of moderately bright parabolic comets. The head is composed of a round nebulosity about 2′ in diameter which grows abruptly brighter at the center where there is a nucleus of about 10″ diameter. This nucleus does not resemble a star but seems to be granular. Extending away from the comet in a direction opposite to the Sun is a well marked tail about a degree long. The tail is moderately broad and there is a widening at the end. There seems to be a fainter nebulosity surrounding the brighter portion of the tail.

The head of the comet is about the brightness of a 7th magnitude star and should be easily seen with a small telescope. C. D. PERRINE.

Lick Observatory, University of California,
March 21, 1898.

GENERAL NOTES.

Professor James E. Keeler Appointed Director of Lick Observatory. On March 8 at a meeting of the Board of Regents of the University of California, Professor James E. Keeler, Director of Allegheny Observatory, Pa., was elected Director of the Lick Observatory. Other candidates were Professor Schaeberle and Professor Davidson. It seemed to be a wish of some members of the Board of Regents to give the position to a resident of the state, and on this account the names of the other gentlemen named would be especially prominent. The choice made is an excellent one, for few other men in this country, if any, are better qualified for such a position than Professor Keeler. It has been thought by some that Professor Keeler would be asked to fill a place in the Yerkes Observatory when the organization of its Staff is completed.

The prospect of losing Professor Keeler from the Allegheny Observatory has stirred up friends in Allegheny and Pittsburgh to do what is possible to retain him in his present position. An effort is being made to raise $200,000 to equip his Observatory at that place. If this is done speedily Professor Keeler will stay at Allegheny. If not it is more than probable that he will accept the position at Lick Observatory.

Professor J. E. Keeler for Director of Lick Observatory.—Since Professor Keeler has been elected to the Directorship of the Lick Observatory by the Regents of the University of California, I am sure he will ably and conscientiously fill that position, should he decide to accept it. E. E. BARNARD.

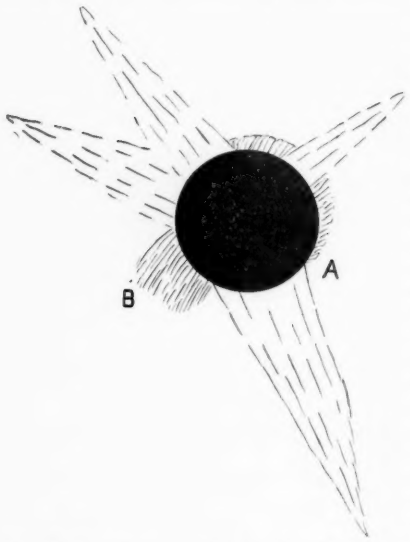
1898, March 21.

J. A. Brashear's Large Contract.—We notice from the papers that J. A. Brashear, of Allegheny City, Pa., was awarded March 16, 1898, a large government contract somewhat novel in character in times of profound peace.

It is reported that the contract is for 125 range finders for use in the Navy and on the land fortifications along the coast; and also 50 telescopes for use on the sea coast for sighting the enemy at long distances. All these instruments must be completed within ninety days. Mr. Brashear has largely increased his force of skilled mechanics and will at the best be crowded to complete so large an order within the specified time. The value of this order is said to be $14,000. If this report is true (which has not yet been verified), the telescope has come to be an engine of warfare, which is in strange and awful contrast with those classic ideas of serene placidity which belong mostly to the nightly vigils of the astronomer.

Total Solar Eclipse in India Jan. 22, 1898.—The accompanying illustration of the solar corona, as it appeared to me on Saturday, Jan. 22, at this place, was drawn immediately after the observation. I looked at it, measuring

the length of the streamers by the diameter of the Moon, and the variations in shape according as they differed from a square. I could also see fainter outlines beyond, gradually fading until lost in every direction. The view given herewith is as it flashed out at first sight. At the last the longest streamer shortened and the two on the opposite side lengthened. The whole corona seemed to me to waver and change as I have seen the northern lights do at my home in America, although I saw no color, only the pearly, silvery white. Especially was the wavering shown in the place marked *B*. I did not see any prominences. One reason may have been that I wished particularly to see the corona, and consequently was not as careful as I should have been about other matters. None of our small party saw the prominences, though others claim to have seen them. Just before the Sun re-appeared something flashed downward in the corona at *A*, which I took to be the herald of the coming Sun. It could not have been a large prominence, for the color would have been noticed.



We were at Jem, where the eclipse was total, and had gone up to a little hill at some distance. At eleven o'clock and forty-two minutes the eclipse began, though it increased so slowly that not till eleven o'clock and forty-five minutes could we say that it was really perceptible. The Sun was very hot and dazzling, so our colored spectacles and white-covered umbrellas were in great demand. A wind sprang up coming from the south-east and it steadily increased in force. At 12:30 it was very high; at 12:45 it was decidedly cooler, and our dark skirts and cushions were no longer hot to the touch. The sky had been changing in hue, and at 12:50 it was dusky blue, much as it is at home just before a snow storm and near the horizon a little of the violet hue appeared. At 1:05 the wind had changed from a steady blow to a fitful one, and still was strong; 1:10 the stones near us were cool, and those in our shadows were decidedly cold. The shadows were faint like those cast by moonlight; 1:12 the wind was chilly; 1:15 faces had a decided livid look—a ghastly bluish tinge; 1:16 the native people were much excited, and we could see them hurrying along through the fields below us. The quiet was settling on everything about us. Birds—a few—were still about, crickets were chirping; 1:20 decidedly like moonlight. The sky near the horizon was pinkish, with a band of faint yellow, between it and the blue. The yellow was about 5° up—all but on the south-west where the shadow was gathering. This was broad, at least 45°, and densely black. We did not see it sweep over us, for at 1:21 the total phase was on, and before we could breathe out flashed the silver corona.

The darkness was not as great as I thought it would be. The light seemed to me to be about the same as it does on a bright moonlight night when

the Moon goes behind a cloud. One bird lighted behind us and gave a bewildered chirp. Venus was bright and visible for two or three minutes before and afterwards, being about 6° from the Sun. I saw no other planets or stars, others did. As soon as totality began the sky maintained the same dusky blue, except for about 10° from the horizon where the yellow light appeared.

One of our party described the corona impression and the light as the effect of an image thrown upon a screen by a magic lantern, and to this thought we all agreed. The length of totality here was two minutes and four seconds, which time went all too soon. Those who were thoughtful and had something white near could see the shadow bands. Miss Abbott said they were like this:

Some others said that the shadows cast were not true shadows, but neither of these things did I see. Tomorrow I expect the papers will have full accounts of observations taken in the vicinity and possibly elsewhere. If so copies will be forwarded.

MARY ETTA MOULTON.

AHMEDNAGAR, INDIA.
Jan 24, 1898.

Buxar.—The general report from this point of observation is given below:

The eclipse was seen here today in all its splendour, and the sight was most impressive. From earliest daylight the country people had been crowding in from all sides, and by eleven o'clock the roads leading to the old fort and the river bank were filled with masses of humanity, the majority armed with baskets of bottles to carry away water which becomes of peculiar sanctity during the eclipse. Three special trains arrived from Calcutta bringing the Viceroy and his guests, besides a great number of European sight-seers. The mail and each ordinary passenger train, as it arrived, also deposited crowds of Europeans and great numbers of natives. The Viceroy's camp was pitched a few miles out of the station on the banks of the canal, but the majority of the European visitors congregated on the walls of the old fort, which was an excellent advantage point and commanded the vast concourse of bathers on the river bank, as well as miles of country to the south west, whence the black shadow of totality was expected to sweep upon us. The sky was absolutely clear, and the clouds of dust raised by crowds below did not reach as far as the walls of the fort. As the black body of the Moon crept slowly over the face of the Sun, the air cooled down very perceptibly, and a breeze sprang up. The gloom grew deeper and deeper, and the green of the spring crops which could be seen for a great distance from the principal roofs in the fort began to assume a curious purple hue, while the gathering of faces became ashy, and the shadows deepened on the ground. The actual sweep of the shadow of the totality was lost in the dust of the horizon, but there was no doubt of the moment when it was upon us, and smoked glass was put aside to watch the marvelous effect which presented itself. The din of the conch shells and the shouting of the people was deafening. Stretching to a distance measured by about twice the diameter of the body of the Sun, now covered by the round coal black shutter of the Moon, were white streamers shooting in straight lines into space. These gathered themselves into four well-marked bunches. At their base was a rim of white glow, the

inner corona. We strained our eyes in vain to see the flame-like prominences that were expected. Near to the Sun came out clearly the planet Venus, but the stars were less easily seen, and the darkness was never really absolute, a dusky twilight continuing throughout, and the sky retaining the green-blue hue of a summer night in the northern latitudes. Totality lasted something short of two minutes, and was broken up by a blinding flash from the lower rim which drove us back to our smoked glasses to witness the drop-like beads of light shining across the ragged edge of the mountains of the Moon.

Total Solar Eclipse Jan. 22, Observed in India.—While it is yet too early to give definite and valuable results of the work of observers in India, it is possible to give some idea of what may be expected later. We copy a few extracts from the Bombay *Times*, Jan. 25, kindly sent us by Miss Moulton whose full and most interesting account of the eclipse with her drawings is elsewhere given in this number. The weather was generally favorable and the observations successful.

Talni. At Talni spectroscopic observations of the Sun preceding the eclipse showed some activity in the chromosphere of Sun generally as was expected in view of existing spots. The correspondent to the *Times* reported that:

The corona was of a delicate, silvery white hue, and as the darkness was not so great as had been expected, its contrasts with the sky was somewhat lessened, but it was an indescribably beautiful spectacle, which fully repaid the observers for all their trouble and expense, and their long journey from England. During the progress of the eclipse, the inhabitants of Talni uttered the most dismal cries, which increased with the darkness. Then there ensued an interval of perfect silence for a few moments, until the Sun reappeared, upon which loud shouts of joy and gladness were heard.

Some of the natives informed one of the observers that the Brahmins predicted that only nine tenths of the Sun would be obscured on this occasion, upon which he advised that they should wait until the 22d of January, and then judge as to who was right. It may appear strange to some, that persons should take such trouble, and incur so much expense, in order to observe an event which lasts for so short a time; but it may be remarked that whilst the corona, and other phenomena, were only taken particular notice of some thirty years ago, that since that date the total combined time available for observations upon them has only amounted to about one hour, which is short indeed when the importance of everything connected with the Sun is considered.

It is too early at present to say anything as to the results of the observations, for the photographs have to be developed and measured, and notes compared.

Total Solar Eclipse Observations at Different Places in India, Jan. 22, 1898.—Norman Lockyer's party observed at Viziadurg, which is thirty miles from Rutnagherry. At the close of the observations Professor Lockyer is reported to have said of the opportunity that "the conditions were absolutely perfect. We set for ourselves twenty-one different lines of work; along each we have been successful." Some plates from the 6-inch and 9 inch prismatic cameras it is reported were at once developed, and it is ascertained that an unique series of photographs were obtained, and that the "flash" was recorded. This was one of the principal things for which the prismatic cameras was used.

At Jeur. The Lick Observatory party under the direction of Professor W. W. Campbell was located at this place. This camp was established by Professor

Naigamwalla, of Poona. It has been reported that Professor Campbell's results could not be given until later, but from all appearances they were favorable. Word from Poona claims that the expedition from that place was very successful. The spectroscopists succeeded in obtaining a spectrum of the reversing layer.

At Pulgaon twelve photographs of the corona and twenty-four photographs of the spectrum were obtained. It is said that they all developed well.

At Sadhol. The observations were taken at this place under a perfectly clear sky. The observations by the Astronomer Royal of England, and Mr. Turner were successful; Mr. Christie exposed seven plates during totality and twenty-four at partial phase obtaining images 4 inches in diameter. Professor Turner took twelve pictures on a smaller scale during totality and two photographs in polarized light. So far as developed the plates were good.

The Northern Durchmusterung.—The Durchmusterung charts of the northern sky are indispensable to every active astronomical Observatory, and to every astronomer who wishes to study the fainter stars. Unfortunately, the original edition of this work is exhausted, so that copies can no longer be supplied. A new edition is being prepared by the Bonn Observatory and will be published shortly, provided that subscriptions for a hundred copies, at seventy marks each, are promised before May 1, 1898. The price is very low considering the amount of material furnished. After that date, the price will be raised to one hundred and twenty marks. The Astronomical Conference, held at the dedication of the Yerkes Observatory, appointed the undersigned a committee to aid this project. Orders for copies may be sent to the publishers, Messrs. A. Marcus & E. Weber, Bonn, Germany, or will be transmitted to them by any member of the committee. It is proposed to publish a list of American subscribers, and it is hoped that, at least fifty copies will be taken by American astronomers. Since charts deteriorate rapidly by constant use several copies should be taken by each of the larger Observatories. The members of the committee have shown their appreciation of the value of this work by ordering twelve copies for use in the institutions under their direction. It is of the greatest importance that the subscription list should be filled as it is probable that in the future many similar enterprises may be undertaken, whose success will depend upon that now attained.

EDWARD C. PICKERING,
J. G. HAGEN, S. J.,
M. B. SNYDER,
} Committee.

Comparison Stars for Variables.—Applications have recently been received from several observers of variable stars for photometric magnitudes of the comparison stars used by them. The measurements described below are available and will be furnished in advance of publication to any astronomer who desires to use them. Sequences of comparison stars have been selected for about one hundred variable stars of long period. Examples of sixteen of these sequences will be found in the pamphlet entitled Variable Stars of Long Period, 4°, Cambridge, 1891. Each of the comparison stars brighter than the tenth magnitude has been measured at least three nights with the meridian photometer. About five stars of each sequence, from the eleventh to the thirteenth magnitude, have been measured on two nights with the photometer having achromatic prisms. (*Astrophysical Journal*, Vol. II, p. 89.) The intervals between the adjacent stars in the sequences have been estimated in grades on three or more nights by Mr. Wendell with the fifteen inch telescope, and by Mr. Reed with the six inch telescope. From

these estimates and measures, a system of magnitudes has been derived, in which the accidental errors are very small, and in which the scale for faint as well as for bright stars is nearly the same in all parts of the sky. This scale, which is that of the meridian photometer, is substantially the same as that of the Potsdam Observatory, and of the Uranometria Oxoniensis, the differences not exceeding one or two tenths of a magnitude. Observations are completed of the variable stars T Andromedae, T Cassiopeiae, R Andromedae, S Ceti, S Cassiopeiae, R Piscium, R Arietis, T Persei, *o* Ceti, S Persei, R Ceti, U Ceti, R Tauri, S Tauri, R Aurigae, U Orionis, R Lyncis, R Geminorum, S Canis Minoris, R Cancri, S Hydrae, T Hydrae, R Ursae Majoris, X Virginis, R Comae, T Virginis, Y Virginis, T Ursae Majoris, R Virginis, S Ursae Majoris, U Virginis, R Hydrae, S Bootis, R Camelopardali, U Herculis, W Herculis, R Ursae Minoris, R Draconis, χ Cygni, S Cygni, R Delphini, U Cygni, V Cygni, T Aquarii, T Cephei, SS Cygni, S Aquarii, R Pegasi S Pegasi, R Aquarii, and R Cassiopeiae, and it is expected that the others will be finished in a few months. An attempt is made at this Observatory to compare, by Argelander's method, the brightness of each of these variable stars once a month. If astronomers elsewhere would reduce their observations to the same scale of magnitudes a uniformity in results would be obtained which is now unfortunately lacking. These measures are now being extended to other variable stars of long period and it is hoped that later all stars of this class may be observed regularly and according to a uniform system.

Photometric magnitudes, determined with the meridian photometer, can also be furnished of many other stars brighter than the tenth magnitude, besides those mentioned above. Volumes XIV, XXIII, XXIV, and XXXIV of the Annals give the magnitudes of all stars from the North to the South Pole, brighter than the sixth magnitude, besides many fainter stars generally distributed in zones at regular intervals of five degrees in declination. Later observations have been made of all stars of the magnitude 7.5 and brighter, north of the declination $-40°$. A redetermination of the brightness of all the stars in the Harvard Photometry is included in this work.

MISCELLANEOUS NOTES.

The variability of a star in the constellation Aquila, whose position is in R. A. $19^h\ 33^m.3$, Dec. $+11°\ 29'$ (1900), has recently been announced by the Rev. T. D. Anderson (*Astron. Nach.* 145, 79.) Measures of 57 photographs give the maximum brightness 9.2, minimum <12.9. The variations can be closely represented by the formula, J. D. $2411550 + 330$ E.

The Rev. T. E. Espin, in Wolsingham Observatory Circular No. 45, calls attention to a red star of the eighth magnitude in R. A. $8^h\ 12^m\ 16^s$, Decl. $+32°\ 19'$ (1855), not contained in the Durchmusterung. This star appears on 30 photographs taken from December 3, 1889 to March 5, 1898, and no variation in light exceeding two or three tenths of a magnitude is indicated. The individual results differ from their mean by $\pm$ 0.13 magn. EDWARD C. PICKERING

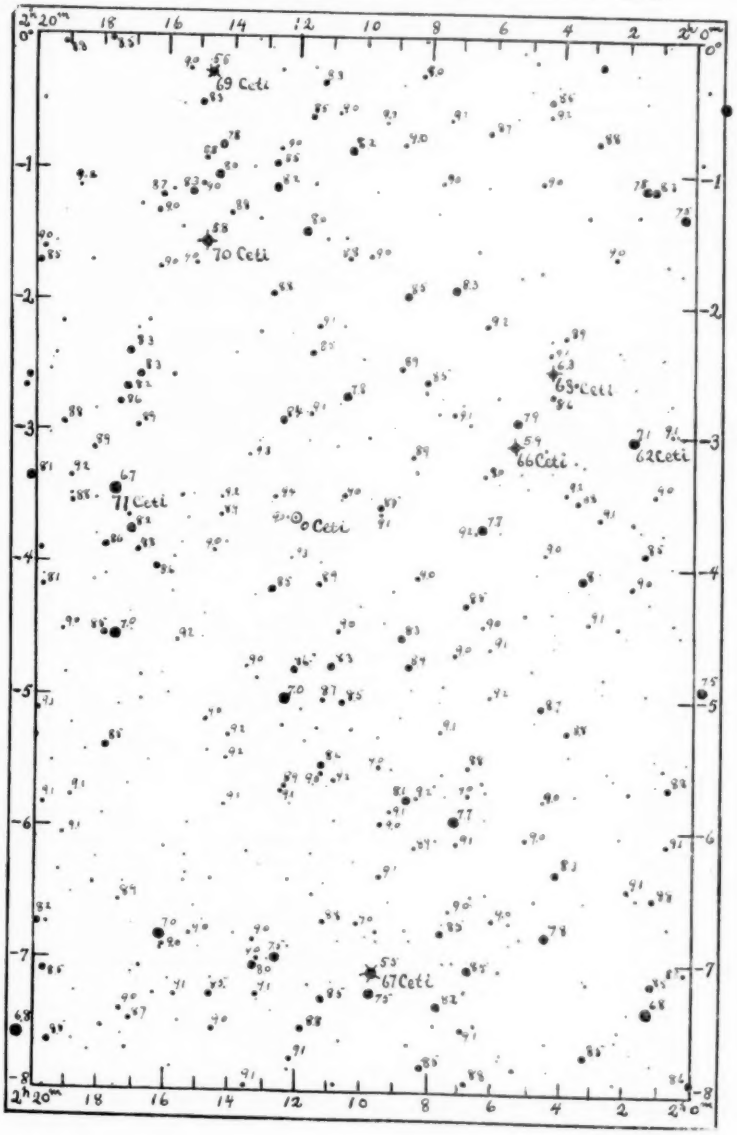
March 7, 1898.

HARVARD COLLEGE OBSERVATORY.

Circular No. 27.

Chart of the *o* Ceti Region.—A short time since one of our readers who is especially interested in variable star observations, requested us to prepare for him a chart of the stars of the Durchmusterung in the of sky about *o* Ceti, with the magnitudes of the stars marked upon the chart. Thinking that others might make use of the same chart, we have had it reproduced for this number of POPULAR ASTRONOMY.

CHART OF THE DURCHMUSTERUNG STARS IN THE VICINITY OF *o* CETI.



The Charles Smith Scott Observatory is being added to the equipment of Park College. This institution is located at Parksville, Missouri, ten miles north of Kansas City. The funds for the Observatory are being furnished by a gentleman in New York City as a memorial of his uncle who was a student of astronomy, in an amateur way.

The Observatory building is of hard limestone tastefully constructed in the pattern known as *broken ashler*. The dome has a diameter of eighteen feet, and the equatorial room which it covers occupies the second story of the main portion of the building. The transit room is a one story annex, on the east side of the part just described.

Temporarily, Mr. Scott's 4½ inch portable equatorial is in the dome room. However, an 8-inch instrument with micrometer is to be put into this room soon. The transit room is equipped with a Warner and Swasey 3-inch combined transit and zenith telescope (a steel instrument of very latest design) a sidereal clock made at the Reifler works in Munich, expressly for this Observatory, a Warner & Swasey chronograph, electrically connected with the clock, and a U. S. Signal Service test barometer and thermometer.

A beginning has already been made of a library of suitable books of reference. About seventy-five dollars worth are already on the shelves and probably twice as many more are to be added at once, and others within a few months. Some of the books immediately available are the standard works on Practical and Spherical Astronomy and on Spectroscopy, quite a number of star catalogues, publications of the Washington and Lick Observatories, and some of the less technical works, such as the writings of Miss Clerke, Professors Langley, Howe, Lockyer, Newcomb, Young, Proctor, Naysmith and Carpenter and others.

The college with which the Observatory is connected is a classical and literary institution, which has not yet undertaken any technical scientific work. But a creditable degree of interest is already manifested, and genuine work in time, latitude and longitude observations, is carried on by the students, under the direction of the professor in charge.

Errata.—Page 34, line 3, for "included" please read "inclined," page 34, line 27, for "7 to 1" please read "10 to 1," page 34, line 7 from bottom, for "but" please read "best," page 36, line 13, for "34" please read "32," page 36, line 2 from bottom, for "doubted" please read "doubled."

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